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PROGRESS REPORT 2

GEOTECHNICAL DATA GATHERING PROJECT

HYDROLOGIC PROGRAM

SECTION 1.2

INTERPRETIVE TEXT

APRIL 15, 1975

TO
AREA OIL SHALE SUPERVISOR
UNITED STATES GEOLOGICAL SURVEY

By
WRIGHT WATER ENGINEERS, INC.
For
Gulf Oil Corporation
and
Standard Oil Company (Indiana)

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TABLE OF CONTENTS

		Page
1.2.0	HYDROLOGIC PROGRAM	1
1.2.0.1	GENERAL GEOLOGY	3
1.2.1	SURFACE WATER MONITORING STATIONS	7
1.2.2	SURFACE WATER DATA COLLECTION	11
1.2.3	ALLUVIAL AQUIFERS	25
1.2.4	DRILLING PROGRAM	26
1.2.4.1	TERMS USED	26
1.2.4.2	WATER PRODUCTION	27
1.2.4.3	WATER QUALITY	29
1.2.4.4	INFORMAL PUMP TESTS	30
1.2.4.5	GEOPHYSICAL LOGS	31
1.2.4.6	SUMMARIZING TABLE	32
1.2.5	COMPLETION PROGRAM	44
1.2.6	UPPER AND LOWER AQUIFER PUMP TESTS	47
1.2.7	DEEP AQUIFER MONITORING	48
1.2.8	DATA INPUT TO MATHEMATICAL MODEL	49
1.2.9	DEWATERING ANALYSIS	50

LIST OF TABLES

Table Number		Page
1.2-1	Location and USGS Identification Numbers For Surface and Rain Gaging Stations	9
1.2-2	Data Collection Schedule For Stream Gaging Stations	12
1.2-3	Drilling Summary Table	34
1.2-4	Drill Hole Completion Summary	46

LIST OF FIGURES

Figure No.		Page
1-2.1	Structure Map on Middle A Groove, Federal Tract C-a	6
1.2-2	Stream Gaging Stations, Rain Gaging Stations and Alluvial Aquifer Monitoring Holes	10
1.2-3	Discharge and Conductivity, Box Elder Gulch Near West Line, Tract C-a	13
1.2-4	Discharge and Conductivity Corral Gulch On West Tract Boundary	14
1.2-5	Discharge and Conductivity Corral Gulch East of Tract	15
1.2-6	Discharge and Conductivity Yellow Creek East of Tract	16
1.2-7	Box Elder Gulch Near West Line, Tract C-a	17
1.2-8	Corral Gulch Near West Line Tract C-a	18
1.2-9	Corral Gulch East of Tract C-a.	19
1.2-10	Yellow Creek Near White River	20
1.2-11	Box Elder Gulch Near West Line, Tract C-a	21
1.2-12	Corral Gulch Near West Line Tract C-a	22
1.2-13	Corral Gulch East of Tract C-a.	23
1.2-14	Yellow Creek Near White River	24
1.2-15	Cross Section Location Map.	25
1.2-16	Hydrologic Cross Section, Section A-A'	38
1.2-17	Hydrologic Cross Section, Section B-B'	39
1.2-18	Hydrologic Cross Section, Section C-C'	40
1.2-19	Hydrologic Cross Section, Section D-D'	41
1.2-20	Hydrologic Cross Section, Section D'-A'.	42
1.2-21	Hydrologic Cross Section, Section D-F	43

LIST OF FIGURES

APPENDIX

Well No.	Fig. 1 Water Prod. & Temp. vs. Depth	Fig. 2 Cond. & pH vs. Depth	Fig. 3 B-Groove Informal Recovery Test	Fig. 4 Total Depth Informal Recovery Test	Fig. 5 Water Velocity & Temp. vs. Depth	Fig. 6 Water Movement vs. Depth	Fig. 7 Well Cross-Sections
CE-701	A	A	C	C	A	A	1
CE-702	A	A	A	A	A	A	2
CE-703	A	A	A	C	A	A	3
CE-705-A	A	A	A	A	A	A	4
CE-707	A	A	A	C	A	A	5
CE-708	A	A	A	A	A	A	6
CE-709	C	A	A	A	A	A	7
AM-2A	B	B	B	B	C	B	8
AM-3	B	B	B	B	C	B	9
AM-4	B	B	B	B	C	B	10
TO-1	C	C	C	C	C	C	11
TO-2	C	C	C	C	C	C	12
TO-3	C	C	C	C	C	C	13
GS-1	14	15	16	17	18	19	20
GS-2-3	21	22	23	24	25	26	27
GS-4-5	28	29	30	31	32	33	34
GS-6	35	36	37	38	39	40	41
GS-7	42	43	44	45	C	C	46
GS-8	47	48	C	49	50	51	52
GS-9	53	54	55	56	57	58	59
GS-10	60	61	62	63	64	C	65
GS-11	66	67	68	69	70	71	72
GS-12	73	74	75	76	77	78	79
GS-13	80	81	82	83	84	85	86
GS-14	87	88	89	90	91	92	93
GS-15	94	95	96	97	98	C	99
GS-M-1	100	101	102	103	104	105	106
GS-M-2	107	108	109	C	110	C	111
GS-M-3	112	113	114	115	116	117	118
GS-M-4	119	120	121	C	122	123	124
GS-D-16	125	126	C	C	C	C	127
GS-D-17	128	129	C	C	C	C	130
GS-D-18	131	132	C	C	C	C	133
GS-D-19	134	135	C	C	C	C	136

A See - Phase II Preliminary Dewatering Analysis Report - Cameron Engineers, 1972
B See - Phase II Preliminary Hydrologic Report for AMOCO, 1973
C No hydrologic data collected

1.2.0 HYDROLOGIC PROGRAM

Rio Blanco Oil Shale Project is conducting the hydrologic program to provide the data for the following determinations: hydrologic, environmental baseline, aquifer characteristics and quality, and quantity of water expected to be produced from various mining plans.

The development of an oil shale operation is under study by Rio Blanco Oil Shale Project. The proposed operation is located in the northwest quarter of the Piceance Creek Basin and is referred to as the Rio Blanco Oil Shale Project (Figure 1). The proposal submitted by Wright Water Engineers for groundwater hydrologic testing and evaluation services on Federal Oil Shale Lease Tract C-a was submitted and approved in July, 1974. The purpose of this study is to collect, report, and initially analyze hydrologic baseline data. Hydrologic data collection from the drilling and coring programs by Rio Blanco Oil Shale Project began in July and were completed in December. Formal hydrologic pump test data, the second phase of study, will be presented in the next quarterly report. Wright Water Engineers has undertaken previous hydrologic investigations in the area. These studies are contained in : "Phase II, Preliminary Dewatering Analysis Report, Cameron Engineers, November, 1972" and "Phase II, Preliminary Hydrogeologic Report for AMOCO, December, 1973". Some of this information is incorporated into this report.

The program has been divided in the nine tasks listed below.

1.2.1 Surface Water Monitoring
1.2.2 Surface Water Data Collection
1.2.3 Alluvial Aquifer Monitoring
1.2.4 Deep Aquifer Drilling Program
1.2.5 Completion Program
1.2.6 Upper and Lower Aquifer Pump Testing
1.2.7 Monitoring
1.2.8 Data Input to Mathematical Model
1.2.9 Dewatering Analysis

The status of progress of each of the nine specific tasks is summarized on the following pages. Of these tasks, baseline data collection for the deep aquifer drilling program, the completion program for upper and lower aquifer monitor holes is essentially completed. Forthcoming reports will include baseline data from more recent information. A current baseline data collection program, including water quality sampling and water level recording, is in progress. General analysis of the data collected, including dewatering analysis, coupled with mathematical model prediction, will be presented in subsequent reports.

This report is divided into two sections. They are the Rio Blanco Oil Shale Project Progress Report 2, Geotechnical Data Gathering Project, Hydrologic Program, Section 1.2 Interpretive Text and Interpretive Text Appendix. The Appendix contains the figures and tables of the data from the drilling and completion programs.

1.2.0.1 GENERAL GEOLOGY

The Piceance Creek Basin is a high plateau reaching 1000 to 4000 feet above the surrounding land. One thousand square miles in area, it is bounded on the north by the White River, and on the South by the Colorado River. The tributaries to the two rivers drain the plateau and have cut deep channels, particularly on the north and south. Overall, the Basin is an assymetric structural downwarp, with a northwest trending axis.

The structural geological center lies twenty miles north of the geographic center of the basin. The Green River Formation reaches a depth of approximately 4,000 feet below the surface. During the Eocene age, the sedimentary Green River formation, which includes oil shale, was deposited in Lake Uinta - the origin of Uinta Basin in Utah. The Piceance Creek basin is an offshoot of Uinta Lake. The north-south trending Douglas Creek Arch partially separated the Piceance Basin from Uinta Lake.

The Mesaverde formation forms the prominent north-south trending Grand Hogback, which dips as steeply as 70 degrees on the east side of the Basin. In the north and east portions of the basin, formation beds dip from 5 to 30 degrees toward the center of the Basin, while the beds in the south and west of the Basin dip much more moderately, from 1 to 5 degrees.

The Tract C-a comprises the Sagebrush Hill, Colorado quadrangle in the northwest quarter of the Piceance Creek Basin. The uppermost bedrock unit in the area is the Uinta Formation. The underlying Green River Formation is made up of the following members, listed in order of oldest to youngest:

- Douglas Creek
- Garden Gulch
- Parachute Creek

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The Douglas Creek and Garden Gulch members, lying under the Tract grade laterally into the Anvil Points member to the east. The Douglas Creek member, of brown and buff sandstone and gray shale, ranges in thickness through the basin from zero to 800 feet. Within the study area, average thickness is 350 feet. The Garden Gulch member is made up of marlstone, shale, sandstone and limestone, with its thickness ranging through the Basin from 300 to 1000 feet. Thickness under the tract is from 350 to 400 feet. In mapping the structural geology of the area, the base used is the top of the Mahogany marker in the upper part of the Parachute Creek member.

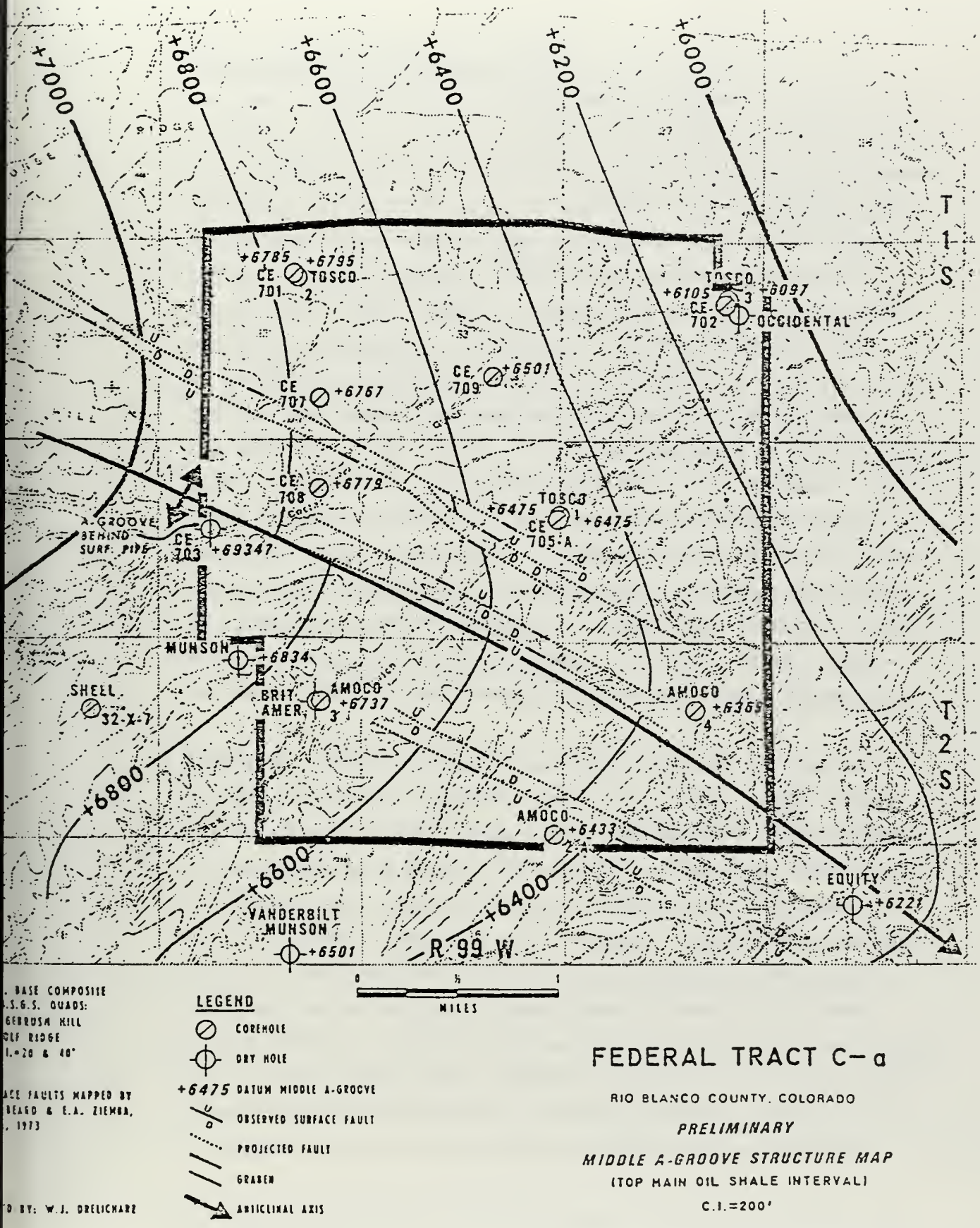
Because the Parachute Creek member is the principal kerogen bearing member in the Green River Formation, it is the primary unit of interest. Toward the top of the unit, a section known as the Mahogany zone averages from 100 to 130 feet in thickness according to several well logs. This zone is rich in oil shale. Directly below the Mahogany zone lies 250 feet of marlstone and shale, low in kerogen content. Beneath the low-grade zone lies another zone of higher yield oil shale.

The uppermost bedrock unit is the Uinta Formation, made up of sandstone, siltstone and marlstone. Subsurface well data and geophysical well logs show thickness in the study area to range from 100 to 700 feet, this variability in the basin being due to surficial weathering. Uinta formation lithology is highly variable; bed continuity is very poor.

A minor alternating anticline-syncline structure underlies the study area. The axis of this structure dips from west to east into the Basin. In addition, a fault system runs through the Tract C-a. See Figure 1.2-1, more detailed structure is presented in the geologic data program.

A northwest trending fault in Tract C-a has a reported measured fault displacement of 200 feet. A series of southeast-northwest

trending faults give definition to a zone of faulting approximately ten miles in length and lying in the study area. A system of northeast-southwest trending joints lies south of the fault zone--evidenced by the trellis pattern of surficial drainage tributaries.



Structure map on middle A-groove, Federal Tract C-a.

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Figure 1-2.1

1.2.1 SURFACE WATER MONITORING STATIONS

In order to establish an environmental baseline for the surface hydrology, the Rio Blanco Oil Shale Project has contracted with the Colorado River Water Conservation District to have the Water Resources Division of the U. S. Geological Survey (USGS) build and operate seven surface gaging stations. Six of the seven gaging stations have been continuously monitoring water flow since March, 1974. Specific conductance and temperature were monitored periodically from March, 1974, to November, 1974, at which time continuous monitoring equipment for specific conductance and temperature was installed in the six stations. The seventh gaging station, located at the mouth of "Rinky Dink" Gulch, has been recording water flow data since November, 1974. These stations consist of a weir built across the stream for measuring water flow rates. In addition to the flow rate, temperature and conductivity is continuously monitored by the use of automatic recording equipment. At periodic intervals, water samples are collected and analyses are run for various chemical constituents as outlined by the Area Oil Shale Supervisor.

Automatic sediment samplers have been installed in order to collect data on the sediment load of the stream. Where there are relatively steady stream flows, the samplers are programmed to take samples at regular intervals. In the case where there are intermittent stream flows, the samplers are programmed to collect sediment samples every 2 minutes. Therefore, good data should be obtained for the flash flood situation showing the sediment load at various stream stages. Three of the seven gaging stations, Dry Fork Station, the Stake Springs Draw Station and the "Rinky Dink Gulch" Station have not had any significant flows since the installation of these stations. Figure 1.2-2 shows the location of the surface and rain gaging stations.

The USGS has installed six rain gaging stations in addition to the surface gaging stations. Three of these stations are of

the storage type gages; precipitation is collected and hand measured at regular intervals. These three stations are associated with the surface gaging stations at Dry Fork, Box Elder and Corral Gulch near the east line of the Tract. The remaining three rain gages are of the recording type in that a precipitation rate, for example, inches per hour, can be monitored. One of these stations is located west of the tract near the drainage divide of Cathedral Bluffs. The second station is located at the surface gaging station near the mouth of Yellow Creek. The third is located at the Stake Springs Draw Station. The location of these surface and rain gaging stations is shown on the attached area map. See Figure 1.2-2.

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TABLE 1.2-1

LOCATION AND USGS IDENTIFICATION NUMBERS
FOR SURFACE AND RAIN GAGING STATIONS

USGS Identification number	Location
09306237	Dry Fork near west line Tract C-a
09306235	Corral Gulch near west line Tract C-a
09306240	Box Elder Gulch near west line Tract C-a
09306242	Corral Gulch east of Tract C-a
09306200	Stake Springs Draw near confluence with Corral Gulch
09306255*	Yellow Creek near White River, Colorado
09306241	"Rinky Dink" Gulch near east line Tract C-a
	Rain Storage-Type Gages
09306235	Corral Gulch near west line Tract C-a
09306237	Dry Fork near west line Tract C-a
09306240	Box Elder Gulch near west line Tract C-a
	Recording Rain Gage
09306230	Stake Springs Draw near confluence with Corral Gulch
09306255	Yellow Creek near White River, Colorado
No number	Cathedral Bluffs located in NW-1/4, NW-1/4, Sec. 14, R100W T2S, R100W

* Was given incorrectly in RBOSP Progress Report 2-Summary

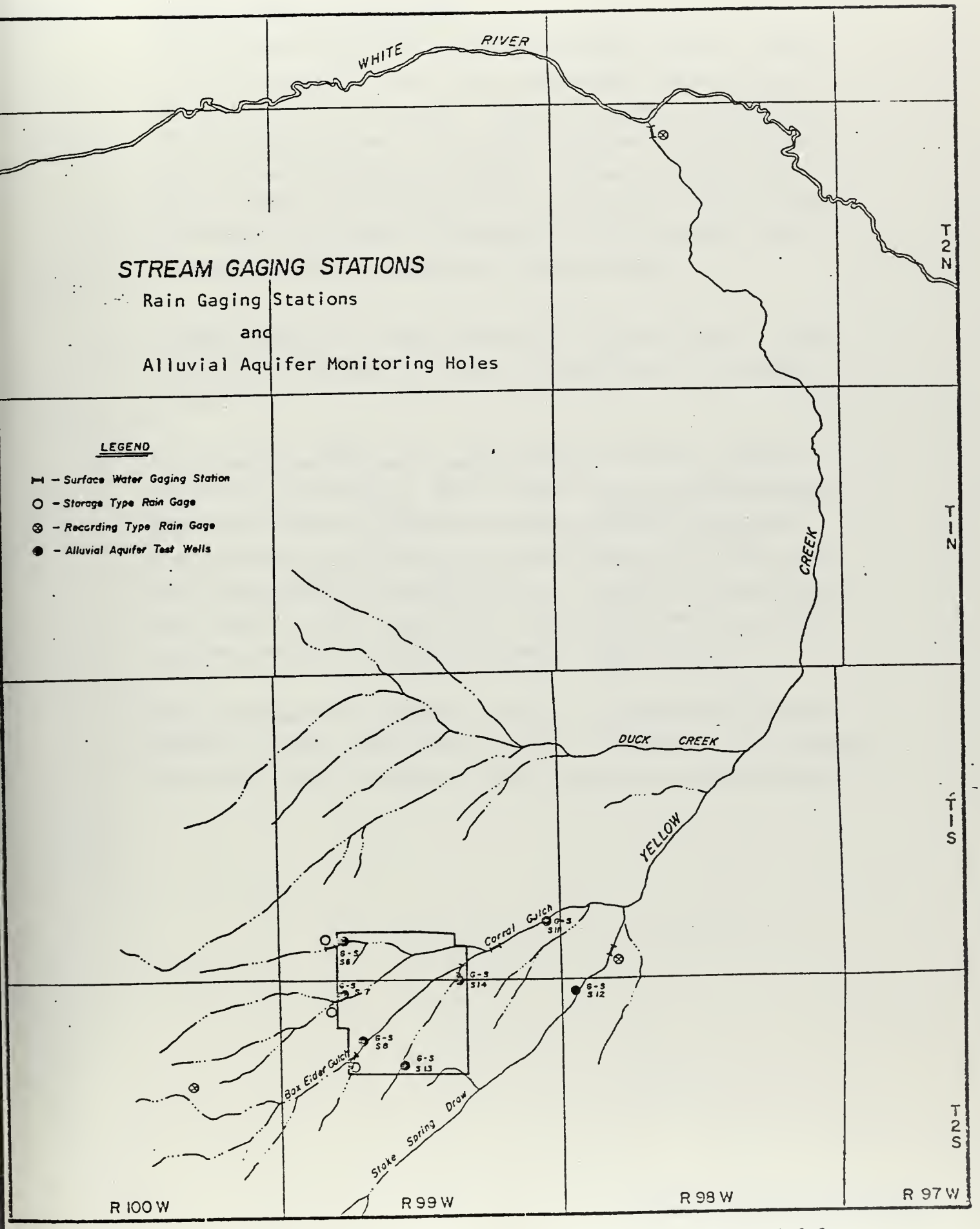
STREAM GAGING STATIONS
Rain Gaging Stations
and
Alluvial Aquifer Monitoring Holes
LEGEND
– Surface Water Gaging Station
– Storage Type Rain Gage
– Recording Type Rain Gage
– Alluvial Aquifer Test Wells
WHITE RIVER
CREEK
DUCK CREEK
YELLOW
Corral Gulch
Box Elder Gulch
Stake Spring Draw
G-S S6
G-S S7
G-S S8
G-S S13
G-S S14
G-S S11
G-S S12
T 2 N
T 1 N
T 1 S
T 2 S
R 100 W
R 99 W
R 98 W
R 97 W

Figure 1.2-2

1.2.2 SURFACE WATER DATA COLLECTION

The first water data were collected on March 14, 1974. Conductivity and temperature have been automatically monitored from November, 1974 to the present. Table 1.2-2 shows the sampling intervals and the type of data being collected for each of the seven surface water gaging stations. The water samples which are collected from the stations are analyzed for various chemical constituents by the USGS laboratories in Salt Lake City, Utah. The analyses will be presented in Progress Report 3.

To date data have not been received from the continuous or automatically collected data for any of the surface or rain gaging stations.

Of the seven surface water gaging stations only four stations reported any discharge in 1974 as shown in the following figures. These four stations include Corral Gulch and Box Elder Gulch near the west line of Tract C-a, Corral Gulch east of Tract C-a and Yellow Creek near the White River. The other monitoring stations appear to have intermittent flows during spring snow melt and heavy runoff as a result of thunder shower activity.

Also indicated on the following figures are conductivity, boron, fluoride, arsenic, and lithium content. As additional data becomes available it will be reported in the appropriate progress report.

TABLE 1.2-2

DATA COLLECTION SCHEDULE FOR STREAM GAGING STATIONS

Continuously or Automatically

Flow Rate
Sediment Discharge
Temperature
Specific Conductance

Periodically

Storage Rain Gages
Recording Rain Gages

Semi-Monthly

Water Samples Analyzed For

Barium	Sulfate	Turbidity
Boron	Zinc	Dissolved Oxygen
Calcium	Ammonia	pH
Chromium (Hexavalent)	Bicarbonate	Arsenic
Copper	Carbonate	Cadmium
Fluoride	Chloride	Lead
Iron	Color	Manganese
Lithium	Dissolved Solids	Mercury
Magnesium	Kjeldahl Nitrogen	Total Phosphate
Potassium	Nitrate	Ortho Phosphate
Selenium	Nitrite	Cyanide
Silica	Odor	Sulfide
Sodium	Oil and Grease	

Quarterly

Sample and Analyze

COD	Radioactivity	Spectrographic Scan
Fecal Coliform	Gross Alpha	67 Elements
Pesticides	4 Picocuries/1	TOC
Polycyclic Aromatics	Ra^{226}	10 mg/1
	Gross Beta	DOC
	100 Picocuries/1	SOC
	Th^{230}	Phenols
	Uranium	Sulfur
		Nitrogen

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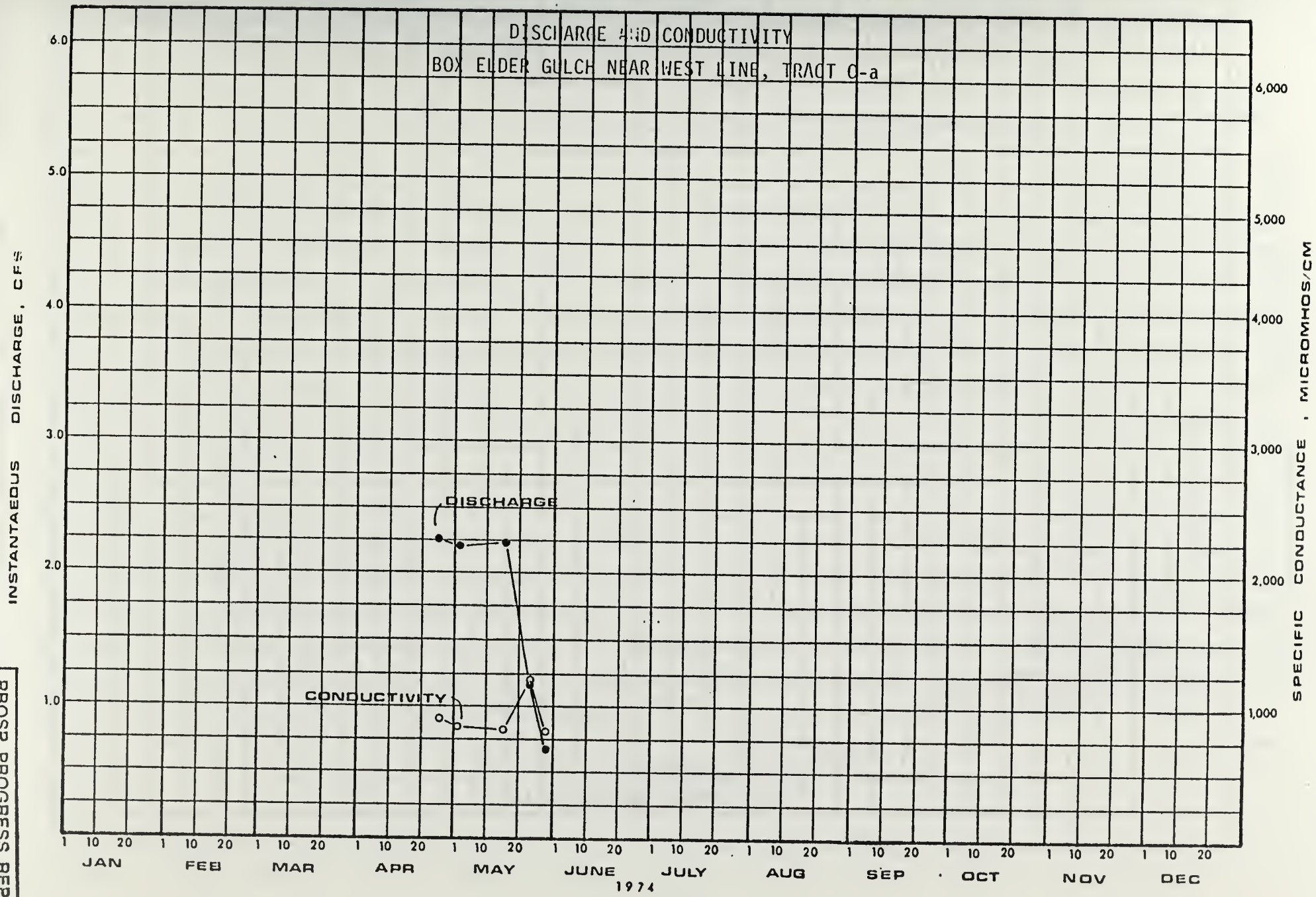
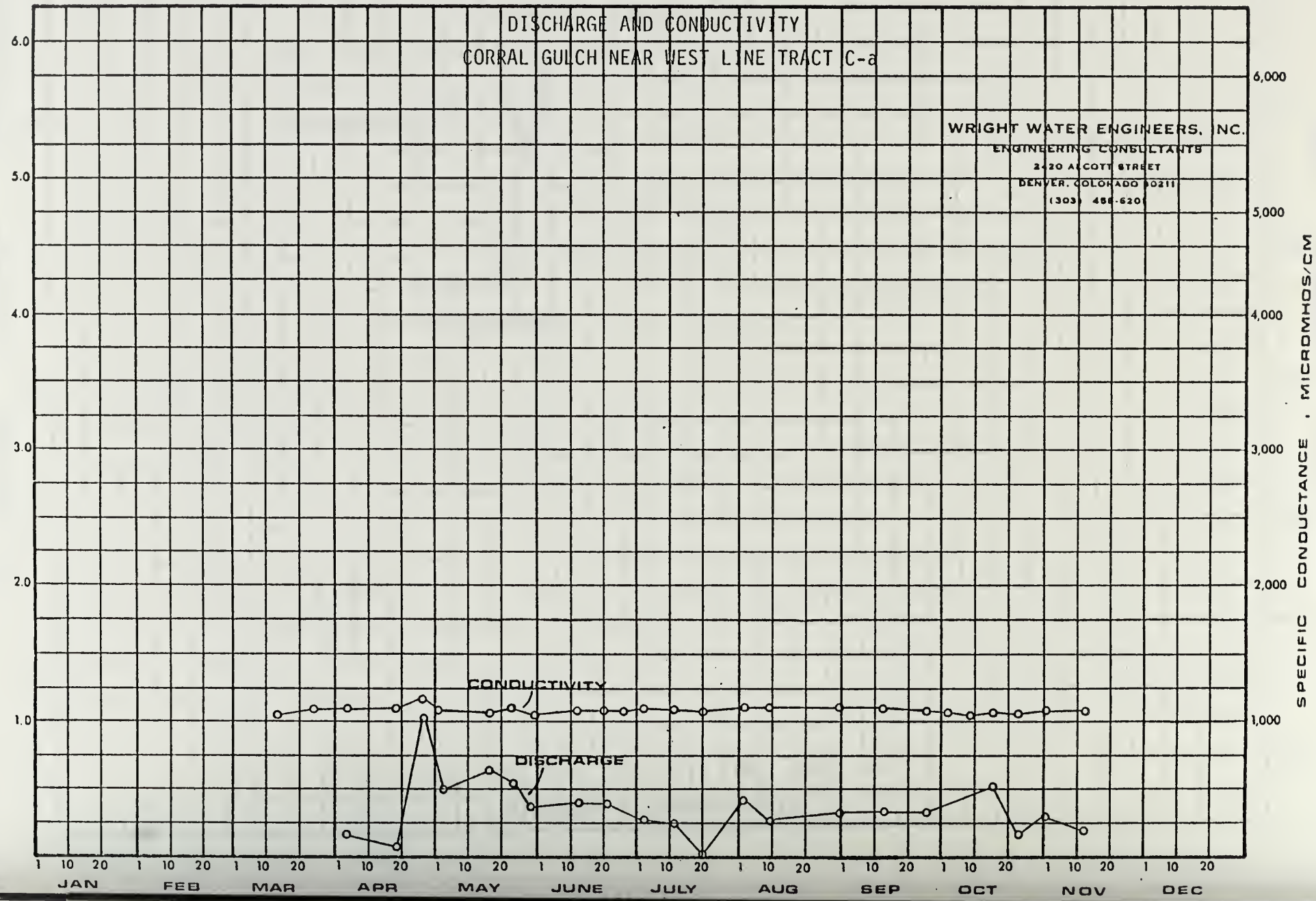

DISCHARGE AND CONDUCTIVITY
BOX ELDER GULCH NEAR WEST LINE, TRACT C-a
INSTANTAEOUS DISCHARGE, CFS
SPECIFIC CONDUCTANCE, MICROMHOS/CM
6.0
5.0
4.0
3.0
2.0
1.0
6,000
5,000
4,000
3,000
2,000
1,000
DISCHARGE
CONDUCTIVITY
1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20
JAN FEB MAR APR MAY JUNE JULY AUG SEP OCT NOV DEC
1974

Figure 1.2-3


DISCHARGE AND CONDUCTIVITY
CORRAL GULCH NEAR WEST LINE TRACT C-a
WRIGHT WATER ENGINEERS, INC.
ENGINEERING CONSULTANTS
2420 ALCOTT STREET
DENVER, COLORADO 80211
(303) 456-6201
INSTANTAEOUS DISCHARGE, CFS
6.0
5.0
4.0
3.0
2.0
1.0
SPECIFIC CONDUCTANCE, MICROMHOS/CM
6,000
5,000
4,000
3,000
2,000
1,000
CONDUCTIVITY
DISCHARGE
1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20
JAN FEB MAR APR MAY JUNE JULY AUG SEP OCT NOV DEC

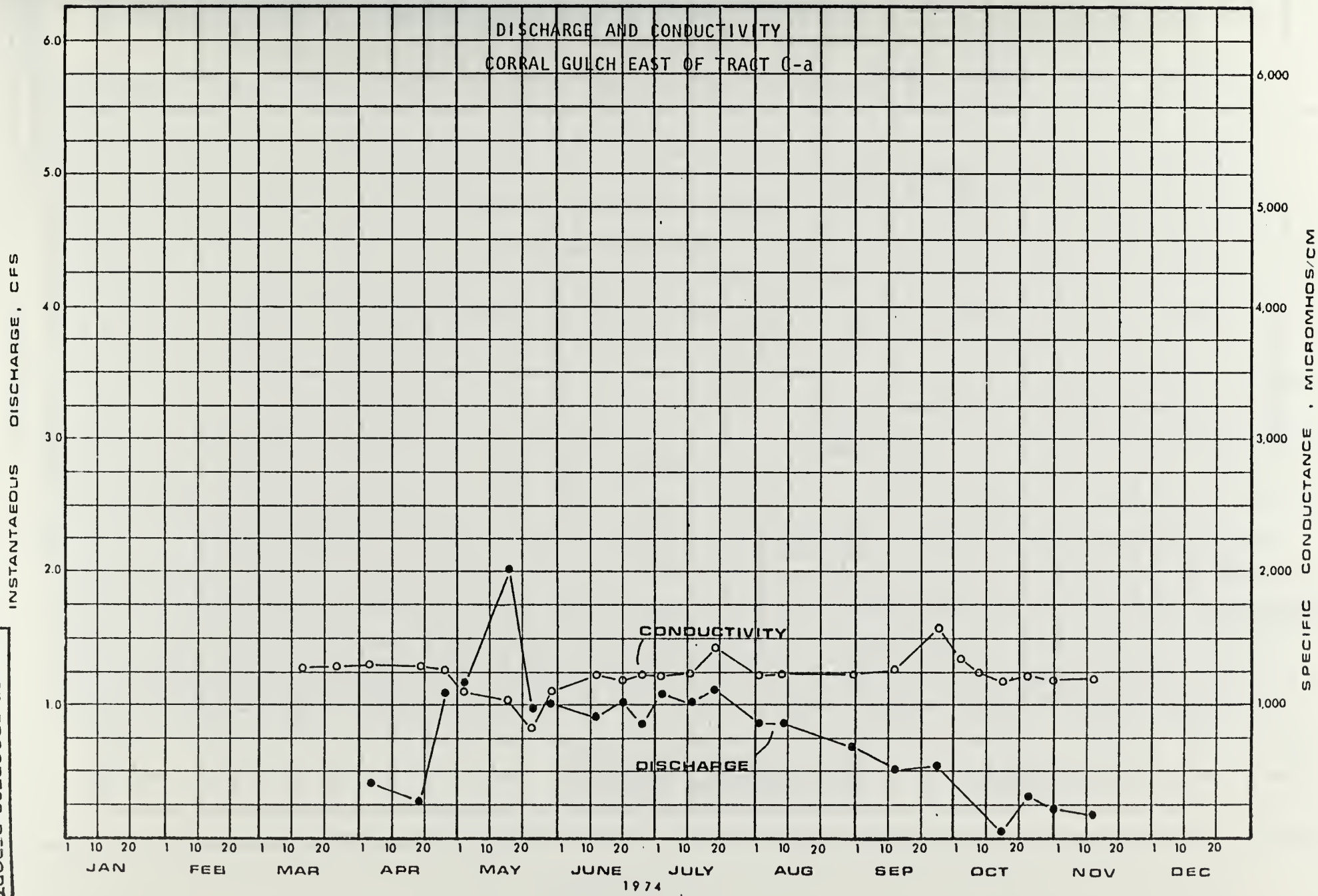
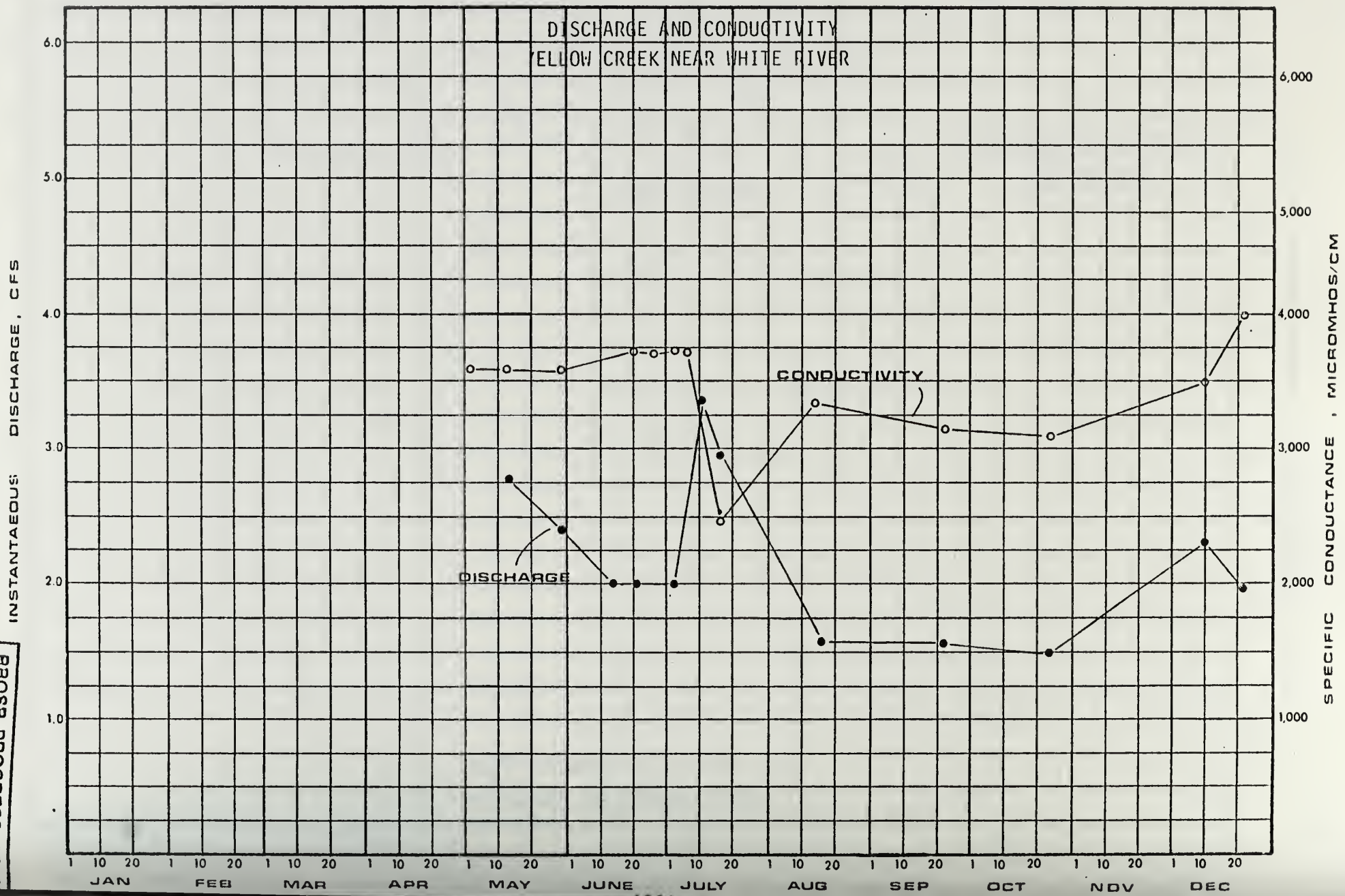

DISCHARGE AND CONDUCTIVITY
CORRAL GULCH EAST OF TRACT C-a
INSTANTAEOUS DISCHARGE, CFS
SPECIFIC CONDUCTANCE, MICROMHOS/CM
6.0
5.0
4.0
3.0
2.0
1.0
6,000
5,000
4,000
3,000
2,000
1,000
CONDUCTIVITY
DISCHARGE
1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20 1 10 20
JAN FEB MAR APR MAY JUNE JULY AUG SEP OCT NOV DEC
1974

Figure 1.2-5



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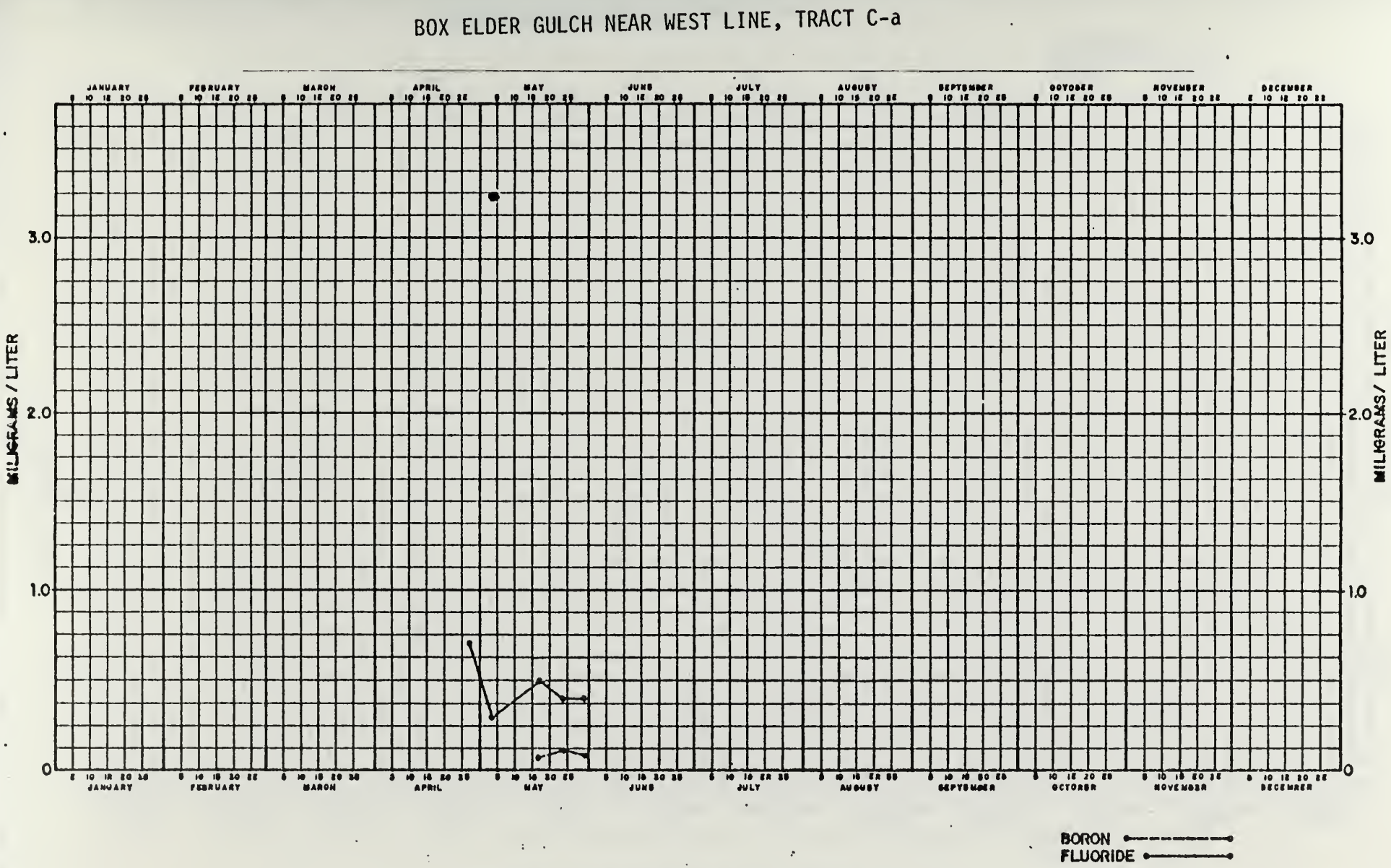

BOX ELDER GULCH NEAR WEST LINE, TRACT C-a
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
MILIGRAMS / LITER
3.0
2.0
1.0
0
BORON
FLUORIDE

Figure 1.2-7

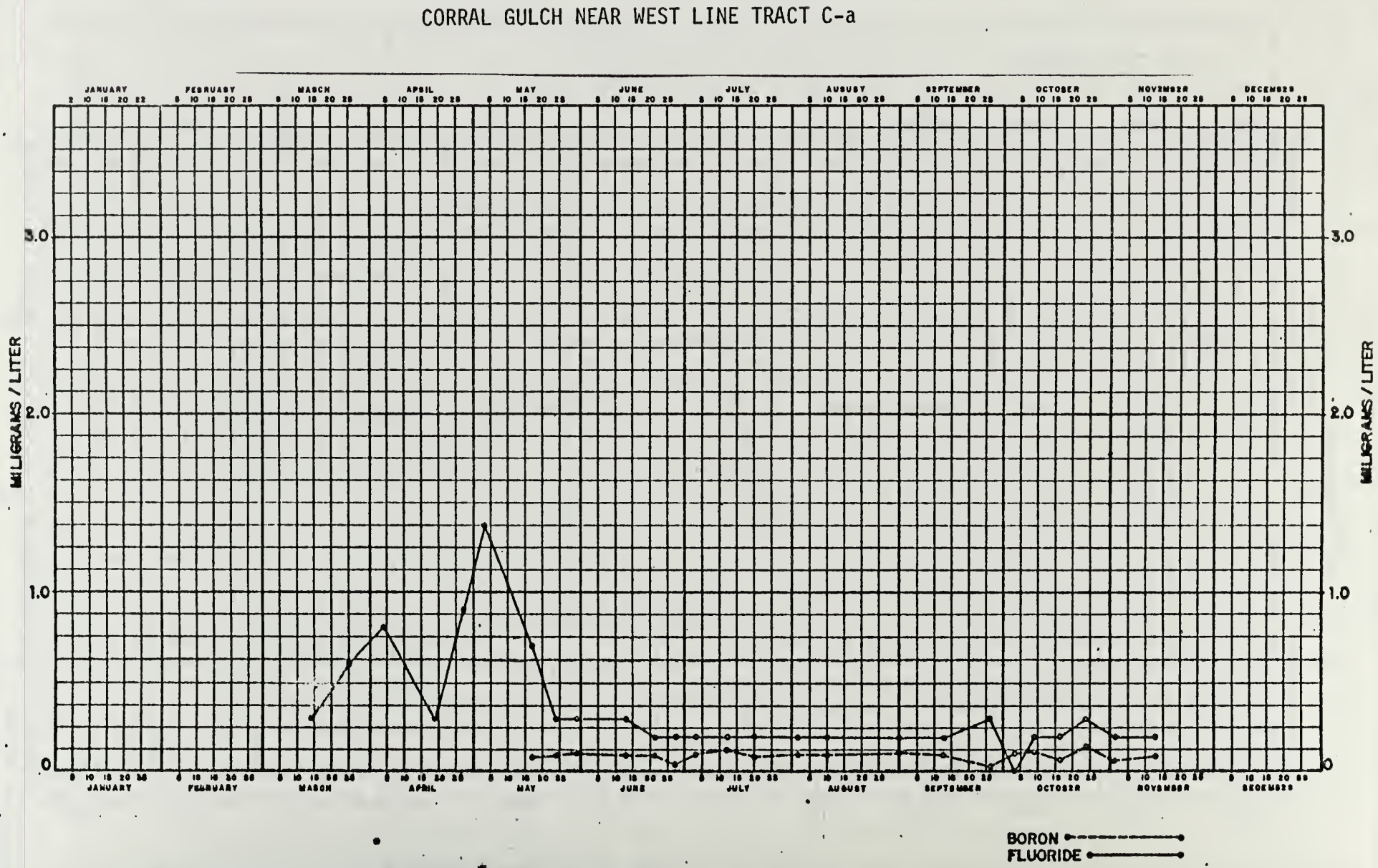
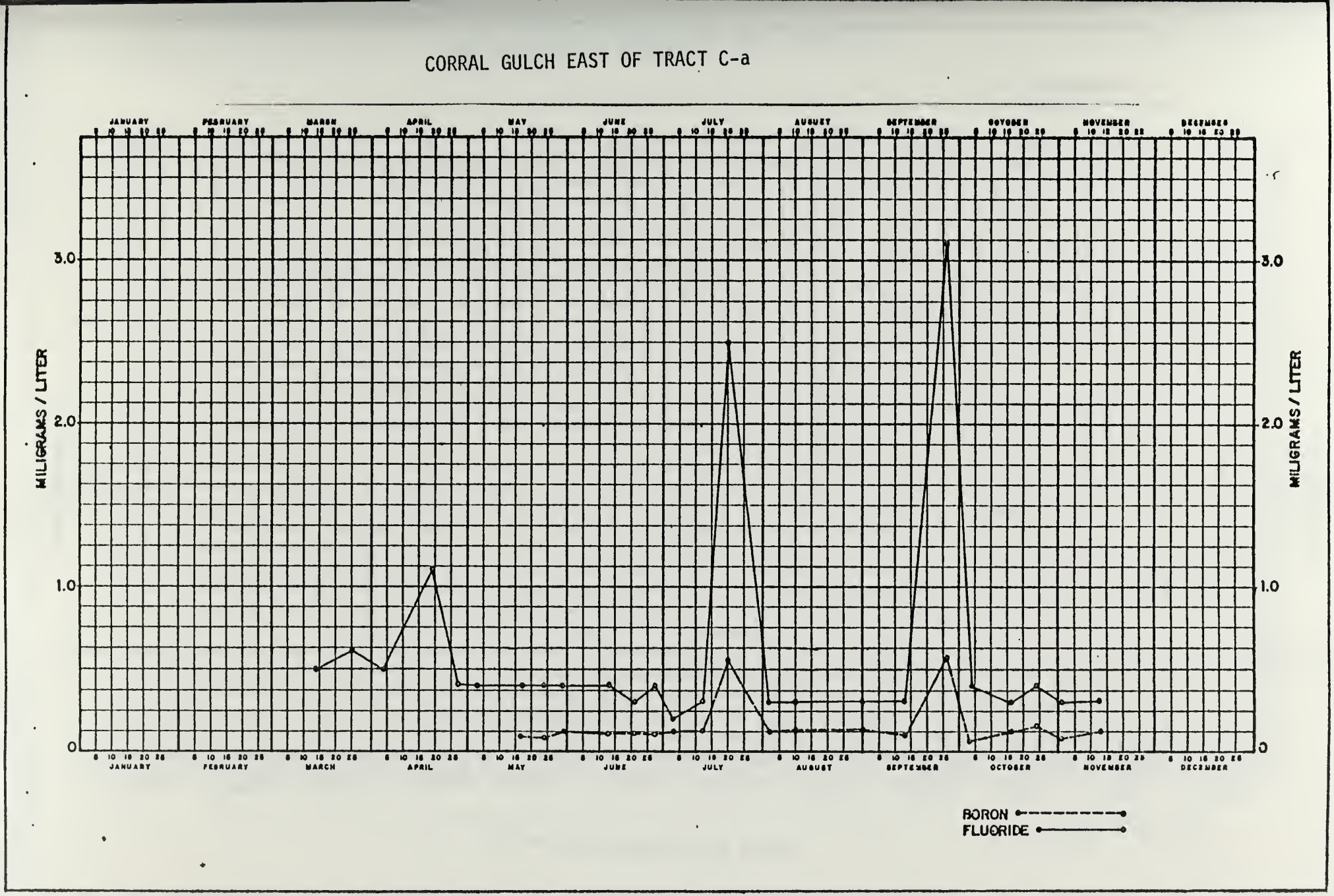

CORRAL GULCH NEAR WEST LINE TRACT C-a
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
MILLIGRAMS / LITER
3.0
2.0
1.0
0
BORON
FLUORIDE

Figure 1-2-8


CORRAL GULCH EAST OF TRACT C-a
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
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AUGUST
SEPTEMBER
OCTOBER
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BORON
FLUORIDE

Figure 1.2-9

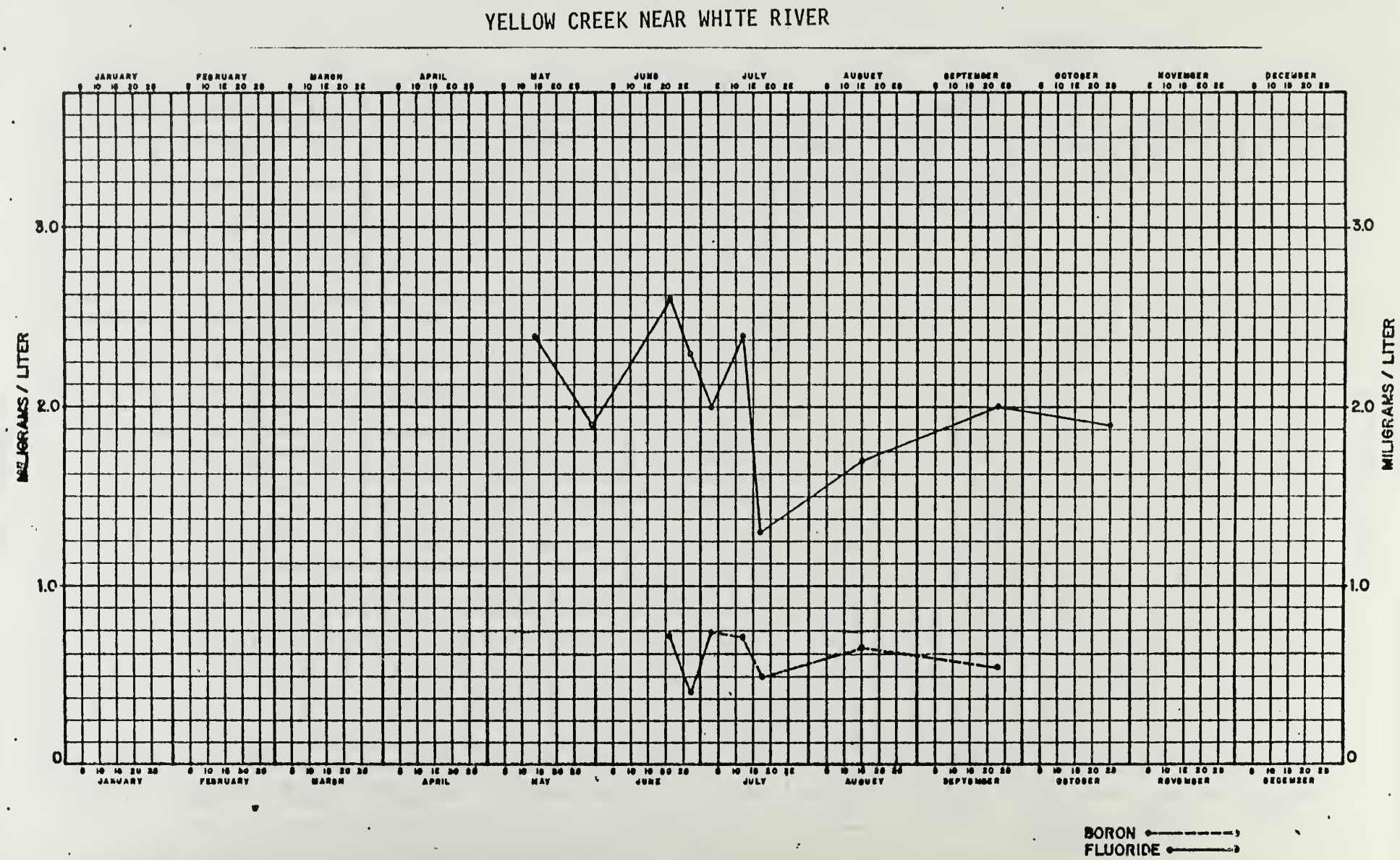

Figure 1.2.10

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BOX ELDER GULCH NEAR WEST LINE, TRACT C-a

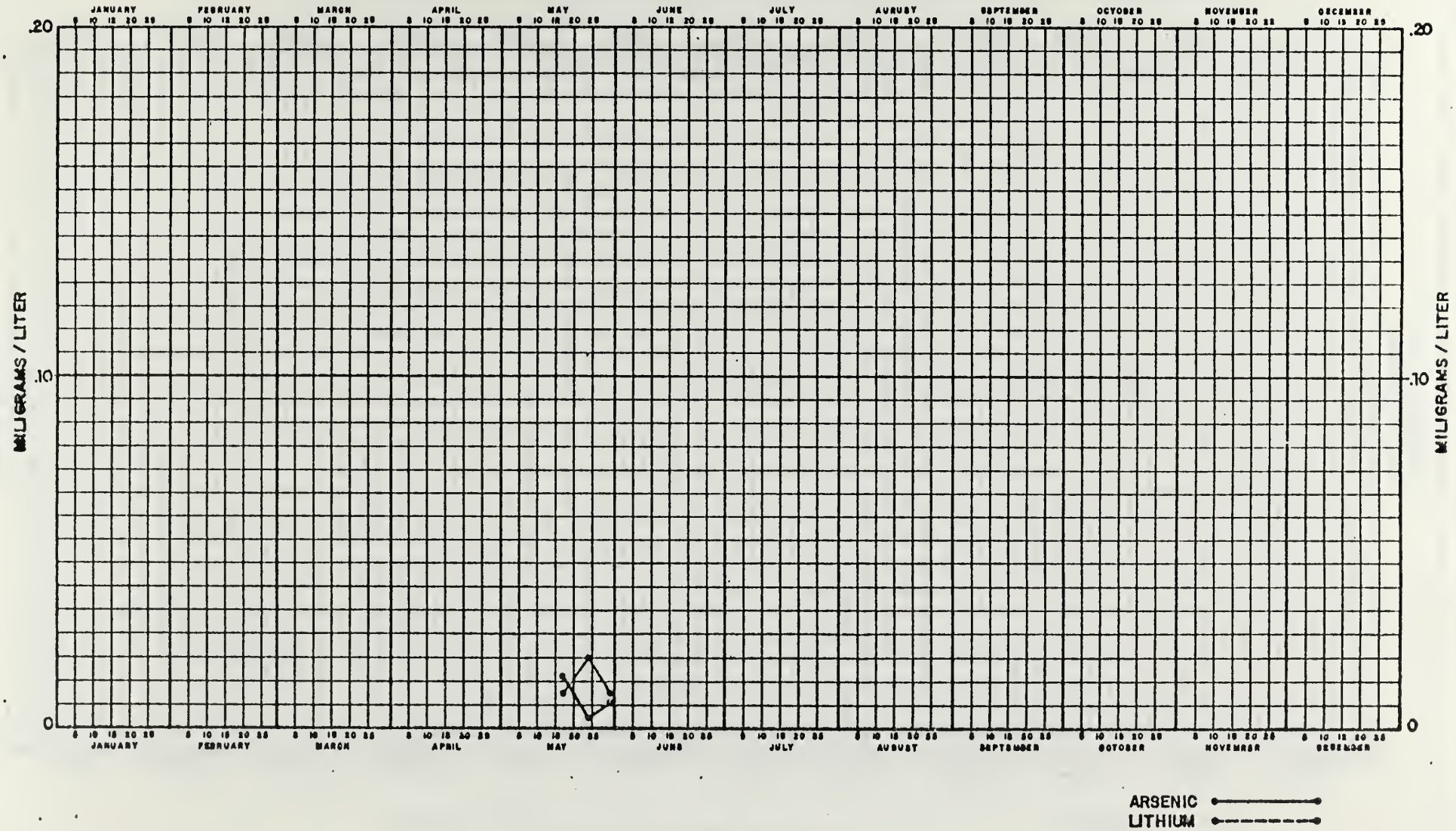

Figure 1.2-11

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CORRAL GULCH NEAR WEST LINE TRACT C-a

Figure 1.2-12

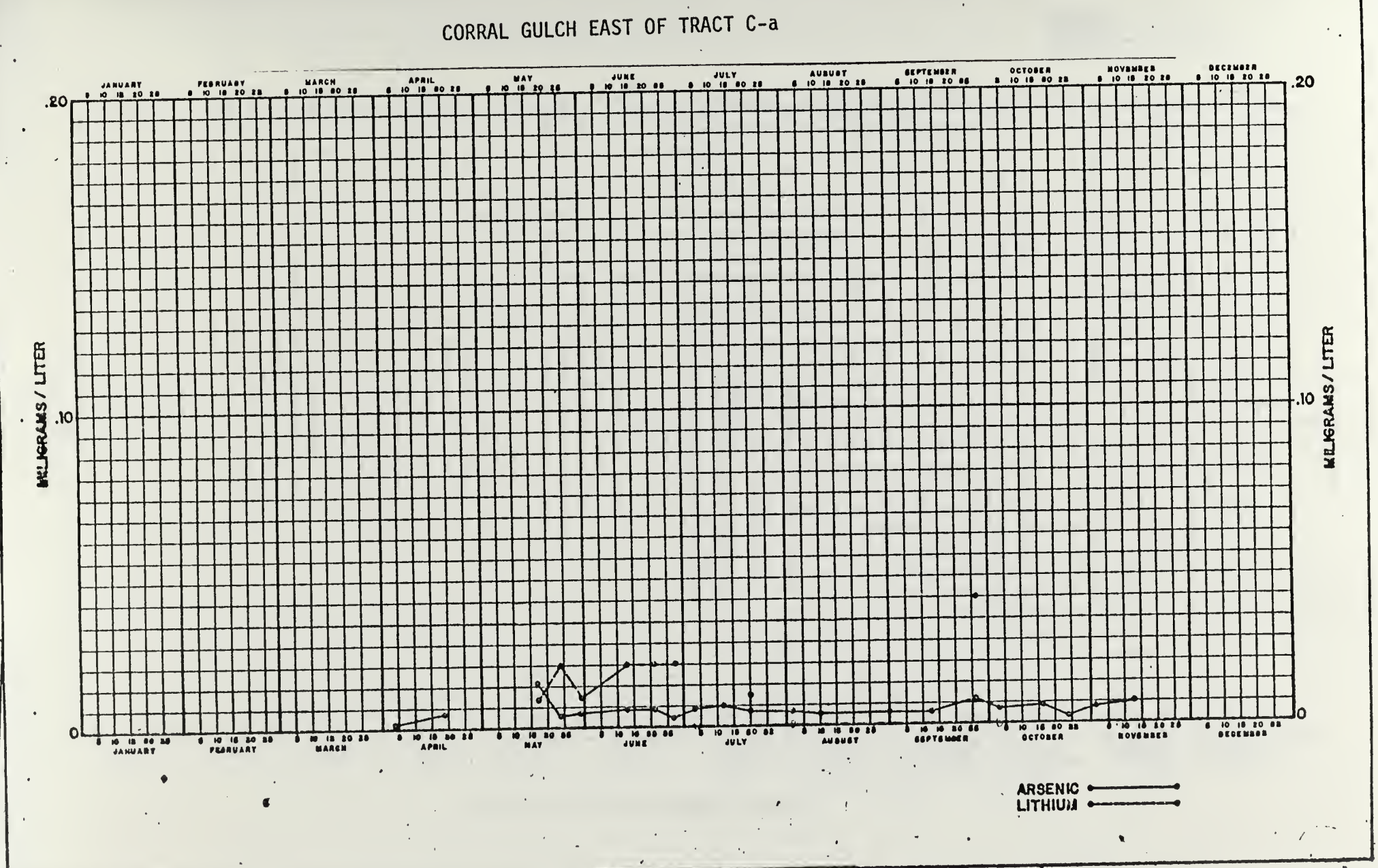

CORRAL GULCH EAST OF TRACT C-a
MILLIGRAMS / LITER
.20
.10
0
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
ARSENIC
LITHIUM

Figure 1.2-13

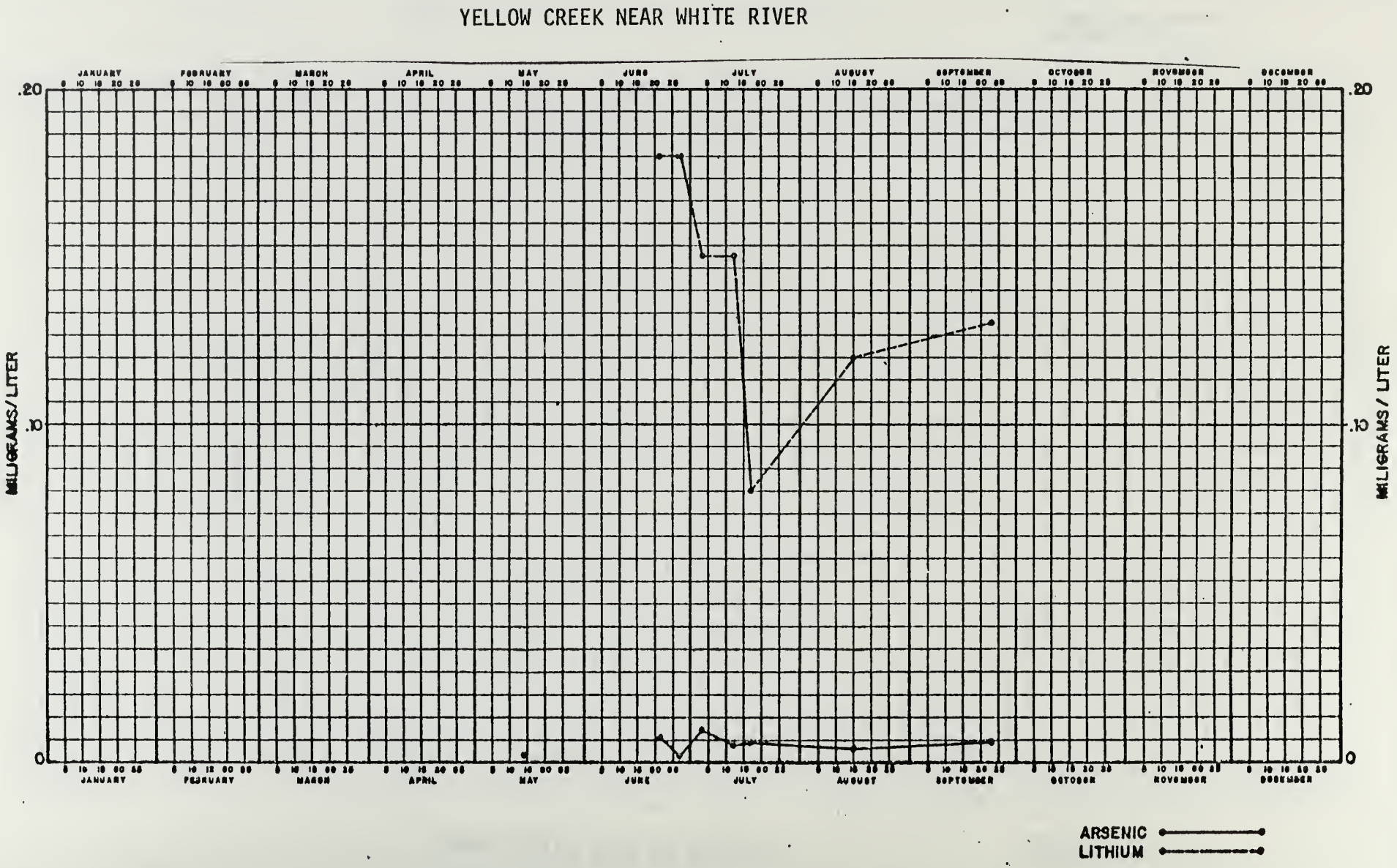


Figure 1-2-14

RBOSP PROGRESS REPORT

1.2.3 ALLUVIAL AQUIFERS

In most of the valley bottoms a variable thickness of alluvial material occurs. Depths ranging from 0 to 140 feet have been measured. In order to monitor and determine if water is present in this alluvium, seven alluvial monitor holes have been completed and are reported in Appendix A of this report.

With the exception of the Yellow Creek gaging station, one monitor hole is associated with each surface gaging station and a seventh monitor hole is located on "Rinky Dink Gulch" just east of the western tract boundary. Four of the seven holes drilled encountered water. These four are G-S S7, G-S S8, G-S S11 and G-S S12. The remaining holes, G-S S6, G-S S13 and G-S S14, were dry when drilled and have not had any water in them up to the time of this report. The first water quality samples were taken during December 1974, for the alluvial aquifer monitor holes. Data from this program is presently being collected and finalized. This information will be presented in subsequent reports.

1.2.4 DRILLING PROGRAM

Several categories of hydrologic data were collected during the drilling and coring of the various holes on and around Tract C-a. This included water production, water quality, informal pump test data, and production logging information. The method and intervals at which this data was collected was based upon the Area Oil Shale Supervisor's stipulations and approvals, and major knowledge from previous area investigations.

Air rotary methods of drilling are reasonably economic and are the best for gathering hydrologic data during drilling in Piceance Creek Basin. Two air rotary rigs were used throughout the drilling and coring program. These were the Carmack Rig No. 10 and the Dreiling Rig No. 1. Western Air Company supplied two primary air compressors and one booster for each driling rig. A mixture of water and biodegradable soapy substance was injected with the air to help lubricate the bit and lift the cuttings. The coring was with a 6-3/4" x 3-1/2" diamond core bit. For the majority of the holes, a 60-foot core barrel was used. A total of 13 core holes, four monitor holes north of the tract, and four large diameter drill holes have been drilled by RBOSP. The drilling and coring program commenced with Core Hole No. 6 during the first week of July, 1974. This program was completed in December, 1974, with large diameter pump hole G-S D19.

1.2.4.1 Terms Used

The following definitions of the terms will be helpful to the reader not familiar with hydrologic reports.

A. Aquifer: A stratum of zone below ground level that contains sufficient saturated permeable material to yield significant quantities of water to wells or springs.

B. Discharge: The rate of flow from the test hole in gallons per minute (gpm).

1 cubic foot per second	= 449	gpm
1 barrel per hour (bph)	0.70	gpm
1 gallon per minute (gpm)	1.43	bph
1 barrel	42	gallons

C. Drawdown: The decrease in the static head of water of the aquifer due to pumping (ft.)

D. Specific Capacity (SC): The discharge from the testhole divided by the drawdown (gpm/ft.)

E. Hydraulic Conductivity (K): The rate of flow in gallons per day through a one square foot cross-sectional area of the aquifer under a hydraulic gradient of one foot per foot (gpd/ft^2).

F. Transmissivity (T): The rate of flow in gallons per day through a vertical strip of the aquifer one foot wide extending the full saturated height of the aquifer under a hydraulic gradient of one foot per one foot (gpd/ft.) The transmissivity equals the hydraulic conductivity times the aquifer thickness.

G. Coefficient of Storage (S): The volume of water released or taken into storage, per unit surface area, when the head on the aquifer is changed by one unit; or the amount of water released from one square foot column of saturated aquifer, in place, when the head on this column is reduced by one foot. The coefficient of storage is referred to as the specific yield or drainable porosity for water table conditions in an aquifer.

H. Artesian Condition: The condition where the piezometric water level is higher than the top of the aquifer, that is, water pressure within a confined aquifer causes water to rise, in a test hole above the top of the aquifer.

I. Water Table Conditions: The case where the water level is equal to or lower than the top of the aquifer.

1.2.4.2 Water Production

Water production was continuously monitored during drilling. This was done because water entering the borehole from a subsurface aquifer during the course of air drilling will be forced to the surface of the hole along with the cuttings. At the surface, air, water and cuttings travel through the "blooey line" to a stilling basin (steel tank) and pit. A 6" x 15" Parshall flume with a Stevens Type F recorder was installed on the outlet of the "blooey pit" to measure water production with respect to time. The production record was then referenced to the drilling depth

record (geolograph) to assist in determining at what depth significant aquifers were encountered. Graphs of water production versus depth for the Gulf-Standard holes are shown in the Appendix of this report.

During the drilling and coring of some of the holes, especially at depths close to total depth, circulation of air, cuttings, and water to the surface was lost. The interval drilled during these periods of lost circulation was as much as 200 feet. Usually, after a period of lost circulation, the hole would flow because of the pressure buildup in the formation. During the drilling of G-S 6, air was observed coming from CE 702. Similar data was also plotted for the Cameron Engineers and AMOCO holes and is reported in the "Phase II Preliminary Dewatering Analysis Report, Cameron Engineers, Piceance Creek Basin, Colorado, November, 1972", and "Phase II Preliminary Hydrologic Report, Colorado Federal Tract C-a, Piceance Creek Basin, Colorado, for AMOCO, December 1973", respectively.

In general, the drilling program indicated the existence of two aquifer systems in the Tract C-a area. Competent oil shale has very little or no permeability and in itself would be a poor medium for an aquifer. However, fracturing, coupled with the leaching of once-existing saline minerals, has created permeability within the oil shales under Tract C-a. The aquifer systems have been delineated and separated on the basis of differences in water quality and water temperature, discussed in the following paragraphs. The upper aquifer describes a water-bearing zone of similar water quality and temperature characteristics which has an upper limit above the Mahogany Zone and a lower limit as far down as the R-5 Zone. The lower aquifer describes a water-bearing zone with similar water quality and temperature characteristics in the vicinity of the R-3 Zone and the Blue Marker. With the exception of G-S 4-5, the water flow in the bore hole after drilling was from the upper aquifer to the lower aquifer. Production from the upper aquifer varied from as little as 40 gallons per minute (gpm) to over 1000 gpm, with an average maximum of 247 gpm. Water produced from

below the top of the lower aquifer, which included production from both aquifers, varied from 150 gpm to over 1000 gpm. The average maximum of combined production was 438 gpm. Table is a summary of all of the core holes and drill holes drilled in and around Tract C-a.

1.2.4.3 Water Quality

Water quality data samples were collected during the drilling and coring of the holes, at the end of the blooey line. At 30-foot depth intervals, conductivity, pH and temperature were measured. Conductivity was obtained using an automatic temperature compensating unit, and a standard conductivity meter. Temperature was measured with standardized mercury thermometers, pH sensitive paper was used to measure pH. The conductivity, pH and temperature data have been submitted to the Area Oil Shale Supervisor.

The conductivity for the upper aquifer ranged from less than 1000 micromhos/centimeter to 1700 micromhos/centimeter with an average of 1290 micromhos/centimeter. For the combined aquifers, the range varied from 1300 to a maximum of 20,000 micromhos/centimeter, the average was 3940 micromhos/centimeter. The lower aquifer water is generally more alkaline than the upper aquifer water. The dissolved solids average 116 milligrams/liter for the upper aquifer and 3235 milligrams/liter for combined aquifer water. The average water temperature from the upper aquifer varied from $54^{o}F$ to $60^{o}F$, averaging $58^{o}F$ while the combined aquifer temperature ranged from $59^{o}F$ to $79^{o}F$.

The drilling of monitor holes G-S M2 and G-S M3 was discontinued several hundred feet short of the anticipated total depth, where the conductivity exceeded 5000 u℧/cm. In consideration of the environment and economics, it would not have been practical to dig pits of sufficient size to contain the water.

RBOSP PROGRESS REPORT

Samples were collected for standard wet chemical and spectrographic analyses, generally, four times during the drilling or coring of each hole. The first sample was taken at a depth where the first significant water production from the bore hole occurred. This could be considered near the top of the upper aquifer. The second sample was taken in the vicinity of the B groove. This sample should represent the water in the upper aquifer. The third sample was taken at the first significant change in water production and water quality below the B groove. Generally, this sample is collected in the vicinity of the R-2 zone and could be considered the top of the lower aquifer. This sample would represent a mixture of waters from the upper aquifer and the upper portion of the lower aquifer. The fourth sample was collected after the hole was completed to its total depth. This sample is a mixture of waters from both the upper and lower aquifers and generally has the poorest water quality. Tables in the Appendix show the results of these analyses for each of the core holes.

In addition to the above four samples collected from each hole, a water sample was collected at 200-foot intervals during the drilling, as required by the Area Oil Shale Supervisor. These samples are presently being stored at the office of Wright Water Engineers.

1.2.4.4 Informal Pump Tests

Informal pump tests were conducted during drilling in order to generally define aquifer properties, such as the transmissivity and the specific capacity. An informal pump test consists of forcing the inflowing water out of the bore hole by injecting air under pressure through the open drill pipe to a point below the aquifer to be tested. This procedure differs from drilling in that the drill bit is off bottom. The "pumping" is continued for two hours (with consequential water level drawdown), during which time water production was monitored. The air compressors were then shut off to allow the water level in the bore hole to

RBOSP PROGRESS REPO

recover for about two hours. From the production rate and the rate of recovery the Jacobs method can be used to approximate transmissivity and specific capacity. In the Appendix are simplified Jacobs plots for the upper and combined aquifers which show corresponding approximate transmissivities and specific capacities. These values are approximate because the pumping period was short, the production rate was not constant, drilling was simultaneously occurring with the production, and the aquifer intervals of varying pressures were open to the bore hole.

The transmissivity indicates the ability of water to move through the aquifer; an aquifer with a high transmissivity can transmit greater amounts of water than an aquifer with a lower transmissivity. The apparent transmissivities for the upper aquifer ranged from less than 1000 gallons per day (gpd) per foot to 20,000 gpd/ft. and averaged 5,140 gpd/ft. The apparent transmissivities for the combined aquifers ranged from less than 200 gpd/ft. to approximately 12,000 gpd/ft. and averaged 3,089 gpd/ft.

The specific capacity is an expression of the production capability in respect to the amount of drawdown experienced at a known production rate. A small specific capacity represents limited aquifer recharge into the well. Apparent specific capacities averaged 1.3 gallons per minute per foot (gpm/ft.) for the upper aquifer and 1.5 gpm/ft. for the combined aquifer tests.

1.2.4.5 Geophysical Logs

A suite of bore hole geophysical electric logs were run after the total depth of each hole was reached. For hydrological purposes, the spinner, a flow-water propeller device which is turned by the force of the flowing water, and temperature surveys are of prime interest. While the spinner surveys are highly interpretive, the temperature surveys are straightforward.

The temperature survey indicates the water temperature in the bore hole versus depth (Appendix). This data can be used in some cases to interpret the flow, being either downhole or uphole, zones where water is entering or leaving the borehole, or no flow at all.

The spinner survey, though interpretive, is more definitive of direction and velocity of flow with hole depth. Measurements are made from these runs. The gallons per minute (gpm) of flow versus depth can be calculated from these measurements with knowing the spinner tool specifications and the bore hole size. The gpm/ft. entering or leaving the borehole can also be calculated.

In general, the upper aquifer was found to be in the vicinity of the Mahogany zone. The lower aquifer was generally in the vicinity of the R-3 zone and the blue marker. With the exception of G-S 4-5, the flow in the bore hole was downward.

1.2.4.6 Summarizing Table

Table 1.2-3 summarized the information gained from the drilling program for Cameron Engineers (CE), AMOCO (AM), and RBOSP--G-S. Some quantities are averages that may have substantial standard deviations. Therefore, this summary is presented as a concise useful guide to hydrologic properties on Federal Tract C-a; for more detailed presentation of specific values and ranges, refer to the Appendix.

Accurate comparison between Cameron, AMOCO and RBOSP hydrologic parameters depends in some cases on the manner in which the data was collected.

The drilling data for Table 1.2-3 was gained from the following sources. The aquifer interval was derived from production logging and from major changes in water quality with drilling depth. Static water levels for the upper and lower aquifers were recently

RBOSP PROGRESS

measured after the wells were converted to dual completion holes. Combined aquifer water levels were recorded during informal pump testing and/or when the wells were completed as open holes with interconnection of the aquifers. The production indicated was that measured from maximum flume recordings. Specific capacities and transmissivities were calculated from informal pump tests conducted during drilling. Therefore, these results were affected by well efficiencies, formation pressurizations and limited test duration; they are considered apparent values. Values were not obtained for Gulf-Standard D holes as informal pump tests were not conducted. Specific conductance was gained by averaging representative temperature compensated values for upper aquifer and combined aquifer water recorded every 30 feet during drilling. Temperatures were derived in a similar manner. Temperatures were not recorded during the initial Cameron drilling phase. pH values for the Cameron drilling program were averaged from water samples collected during drilling that were laboratory analyzed. Gulf-Standard pH results were taken from field data recorded during drilling. Average dissolved solids were calculated from laboratory analysis of drilling samples.

CORE HOLE		CE-701	CE-702	CE-703	CE-704c	CE-705A	CE-706	CE-707	CE-708	CE-709	U.S.B.M. #2	AM-2a	AM-3
AQUIFER INTERVAL feet	Upper	220-310	350-440	680-740	620-780	220-440	130-840	200-560	150-300	120-510	957-1450	420-980	270-400
	Lower	940-1020	1375-1540	1250-1315	1480-1600	820-1100	1120-1320	1040-1360	800-880	980-1260	1673-2075	1510-1610	750-920
STATIC WATER LEVEL feet	Upper (as of 1-15-75)	156	53	(40)	70	(35)	150	274	55	53	250	419	45
	Composite	320	68	240	180	60	335	566	150	90	275	537	255
	Lower (as of 1-15-75)	(380)	6	(280)	190	(160)	400	545	272	130	600	606	283
PRODUCTION RATE gpm (Maximum)	Upper	50	200	45	300	340	400	40	70	700	400	277	100
	Combined	285	655	--	880	730	600	240	470	780	510	255	289
APPARENT SPECIFIC CAPACITY gpm/ft.	Upper	(1)	5	.2	--	--	1.5	.2	1	20	--	--	.2
	Combined	(2)	10	(2)	--	(2.7)	15	--	4	--	.5	.5	10
APPARENT TRANSMISSIVITY t_1, gpd/ft.	Upper	2000*	36,000	1000*	2200	3000	3000	900	3800	19,000	5000	3200	700
	Combined	4000*	27,000	500	--	10,000	20,000	--	5400	--	500	8100	47,500
AVERAGE SPECIFIC CONDUCTANCE umhos/cm	Upper	1100	900	2800	1000	1000	1250	1300	1100	1100	1000	1300	1100
	Combined	1500	3000	2800	2600	1700	1400	2500	2000	1150	1200	2600	5000*
AVERAGE TEMPERATURE °F	Upper	--	50	--	--	54	--	52	57	51	--	60	55
	Combined	--	72	--	--	56	--	53	63	54	--	72	66
AVERAGE pH	Upper	8.0	7.9	8.4	8.6	7.4	7.5	8.0	8.0	7.7	8.2	8.4	8.2
	Combined	8.3	8.1	8.3	8.4	8.1	8.0	7.9	8.0	7.8	8.1	8.4	8.4
AVERAGE DISSOLVED SOLIDS milligram/liter	Upper	1000	800	1000	800	800	900	1000	1000	900	600	1000	700
	Combined	1500	2200	1300	2400	1600	2200	1700	1900	900	650	1400	3900

*Representative value

**E logs

Table 1.2-3

	CORE HOLE	AM-4	TO-1	TO-2	TO-3	GS-1	GS-2-3	GS-4-5	GS-6	GS-7	GS-8	GS-9	GS-10	GS-11	GS-
Upper	AQUIFER INTERVAL feet	730-950	See 705a	See 701	See 702	260-450	180-470	220-650	180-630	200-400±	400-720	410-610	640-820	670-910	580-
Lower		1400-1920				900-1230	920-1200	1050-1400	1300-1780	1000-1200	1060-1460	1070-1240	1380-1600	1350-1480	1280-
Upper	STATIC WATER LEVEL feet	448	29	140	50.5	245	117	75	10	(10)	(340)	323	340	478	407
Composite		466				270	180	65	50	250	520	370	350	580	560
Lower		488	101	322	--	580	208	65	51	--	623	487	360	691	619
Upper	PRODUCTION RATE gpm (Maximum)	130				100	200	560	375	80	70	140	280	125	100
Combined		265				160	500	865	575	250	250	300	455	310	300
Upper	APPARENT SPECIFIC CAPACITY gpm/ft.	--				.43	1.7	3.6	.50	.46	--	.5	1.6	3.7	
Combined		--				.18	.85	6.4	.24	1.1	.84	.63	.24	1.2	1
Upper	APPARENT TRANSMISSIVITY t_1, gpd/ft.	250				--	2800	7900	14,700	770	--	--	2960	1200	2400
Combined		--				300	1800	10,500	420	2400	1050	1220	570	1640	12,000
Upper	AVERAGE SPECIFIC CONDUCTANCE umhos/cm	1400				1000	1160	1800	1200	1000	1100	1520	1160	980	1700
Combined		3900				2055	2760	2850	2840	1500	2250	2800	4500	3700	3100
Upper	AVERAGE TEMPERATURE °F	60				57	59	60	59	57	59	58	61	58	59
Combined		80				59	71	76	75	62	64	69	79	71	70
Upper	AVERAGE pH	7.8				6.7	7.0	6.7	7.6	7.0	7.0	6.7	7.1	7.0	7
Combined		8.5				6.8	7.4	7.5	7.9	7.0	7.5	7.4	8.1	8.1	7
Upper	AVERAGE DISSOLVED SOLIDS milligram/liter	1000				1350	1000	1000	.840	800	720	1300	1250	1700	2000
Combined		2700				3440	2300	1900	3600	1280	1400	2100	1900	2940	3000

*Representative value
**E logs

Table 1.2-3 continued

AQUIFER CHARACTERISTICS FROM DRILLING

	CORE HOLE	GS-13	GS-14	GS-15	GS-M1	GS-M2	GS-M3	GS-M4	GS-D16	GS-D17	GS-D18	GS-D19
Upper	AQUIFER INTERVAL feet	510-840	680-780	600-700	600-800	360-1160	100-1000	840-960	580-620	220-310	350-440	220-440
Lower		1280-1380	1200-1400±	1300-1400	1360-1500	1980-2030	1450-1650	1720-1990	128-1430	940-1020	1375-1540	820-1100
Upper	STATIC WATER LEVEL feet	387	(330)	279	643(50)**	241	22	487	--	--	--	--
Composite		510	410	320	700	320	90	540	--	--	--	--
Lower		543		334	798	348	128	535	--	--	--	--
Upper	PRODUCTION RATE gpm (Maximum)	120	40	100	20	440	1020	200	190	120	1060	360
Combined		375	300	500	150	510	1000	260	230	85	415	660
Upper	APPARENT SPECIFIC CAPACITY gpm/ft.	2.8	.43	2.8	.3	2.2	8.2	.9	--	--	--	--
Combined		2.3	3.3	.66	.4	--	3.3	--	--	--	--	--
Upper	APPARENT TRANSMISSIVITY t_1, gpd/ft.	4600	1700	7600	510	2600	12,000	1200	--	--	--	--
Combined		3300	5000	600	410	--	8800	--	--	--	--	--
Upper	AVERAGE SPECIFIC CONDUCTANCE umhos/cm	1100	1100	1100	1200	1000	1040	1500	1200	1200	2200	950
Combined		2800	2950	3400	3400	8200	16,500	3840	4200	1500	4800	1750
Upper	AVERAGE TEMPERATURE °F	55	58	59	54	61	54	61	56	56	58	53
Combined		70	72	76	67	71	61	72	67	56	77	61
Upper	AVERAGE pH	7.0	6.8	7.1	6.9	7.1	6.9	7.1	7.0	6.9	7.2	7.0
Combined		7.6	8.4	8.3	8.5	7.8	8.5	7.9	8.6	7.1	8.6	7.3
Upper	AVERAGE DISSOLVED SOLIDS milligram/liter	1370	1050	1150	800	800	900	950	1400	950	1600	830
Combined		2300	2250	2500	2600	--	18,000	1950	2900	1300	3780	1800

*Representative value
**E logs

Table 1.2-3 continued

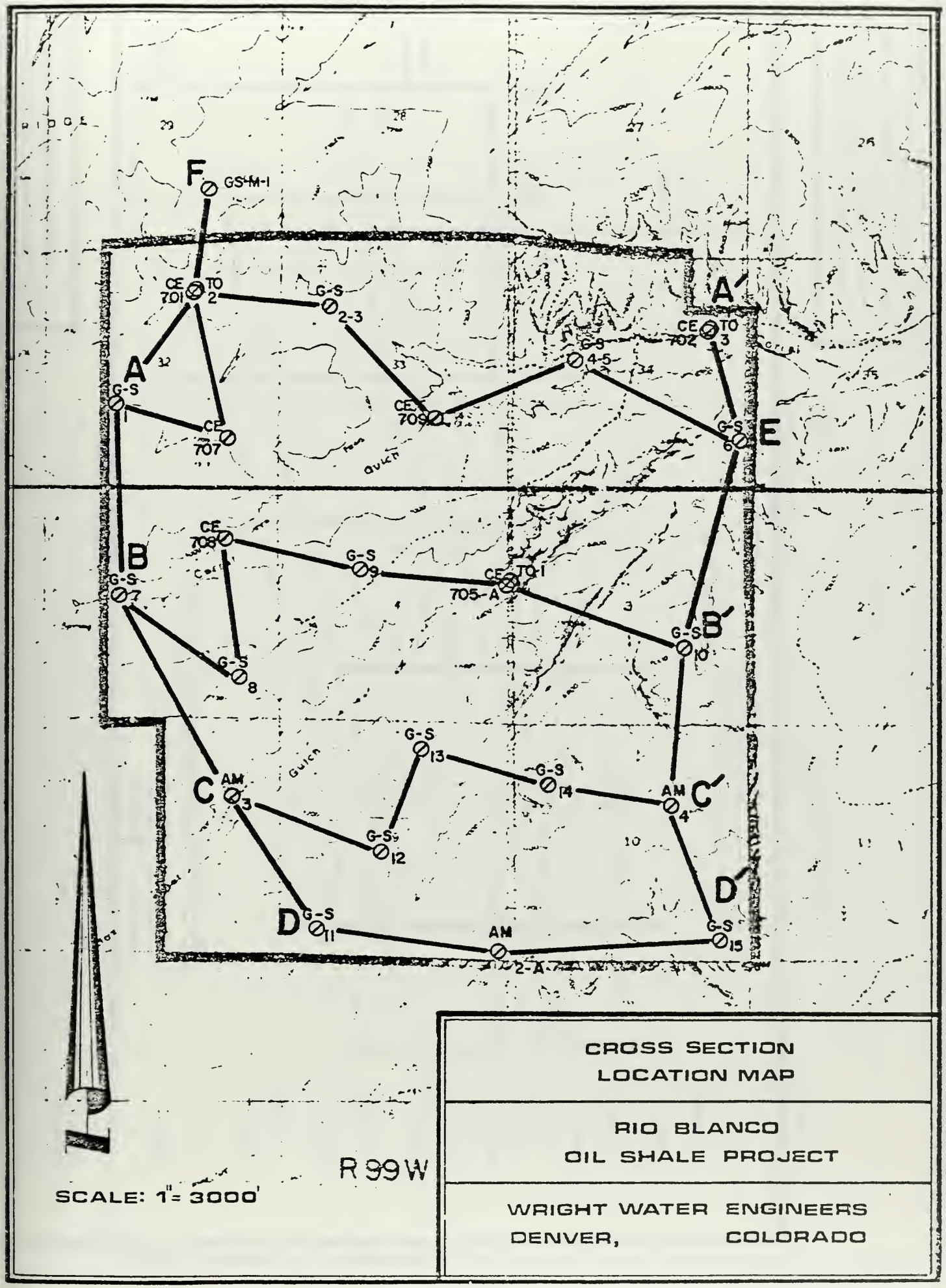
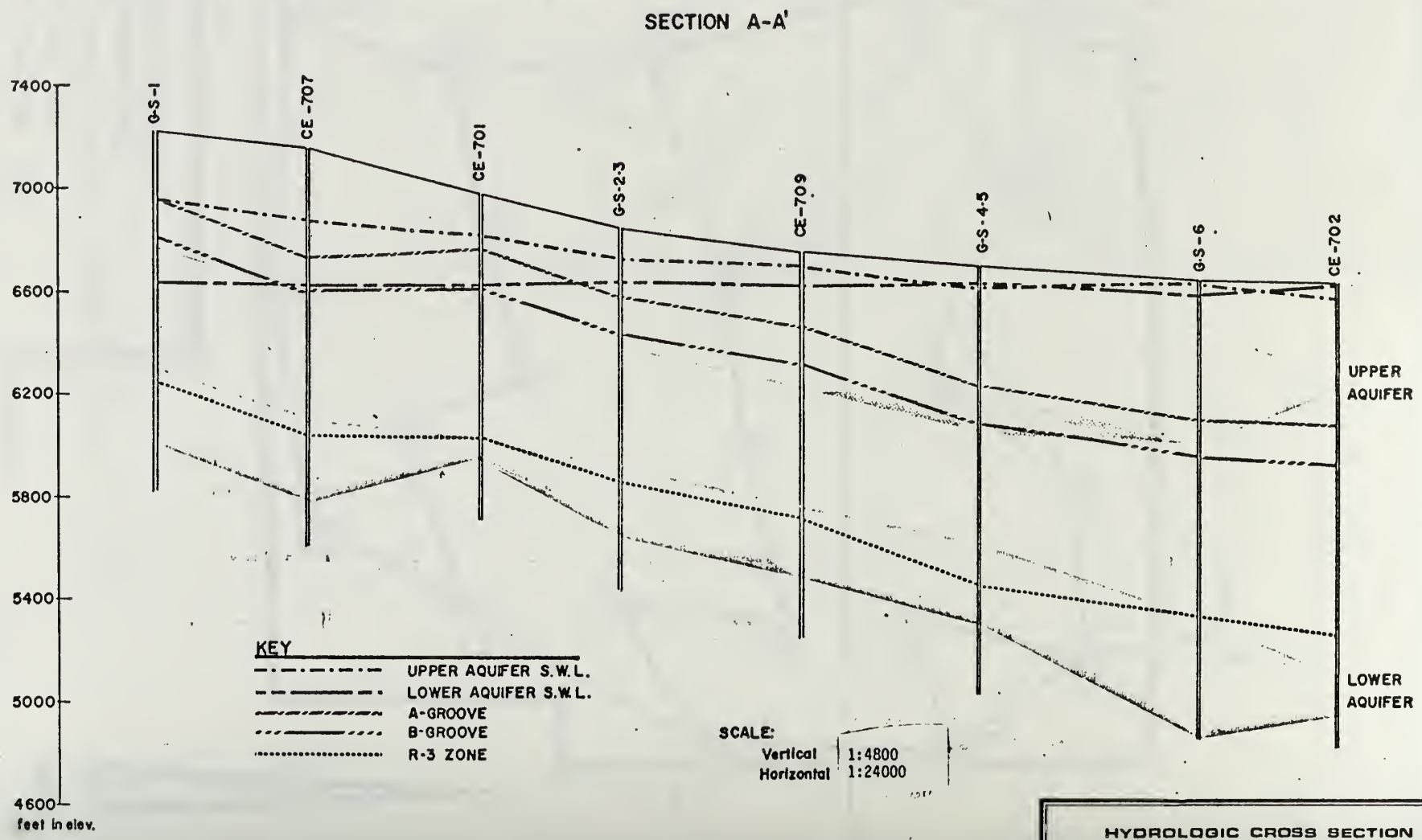

F
GS-M-1
CE 701
TO 2
G-S 2-3
A
G-S 1
CE 707
CE 709
G-S 4-5
CE 702
TO 3
A'
G-S 6
E
CE 708
B
G-S 7
G-S 9
CE 705-A
TO-1
G-S 10
B'
G-S 8
G-S 13
G-S 14
C
AM 3
G-S 12
AM 4
C'
D
G-S 11
AM 2-A
G-S 15
D'
R 99 W
SCALE: 1" = 3000'
CROSS SECTION
LOCATION MAP
RIO BLANCO
OIL SHALE PROJECT
WRIGHT WATER ENGINEERS
DENVER, COLORADO

Fig. 1.2-15



HYDROLOGIC CROSS SECTION

RIO BLANCO OIL SHALE PROJECT

Figure 1.2-16

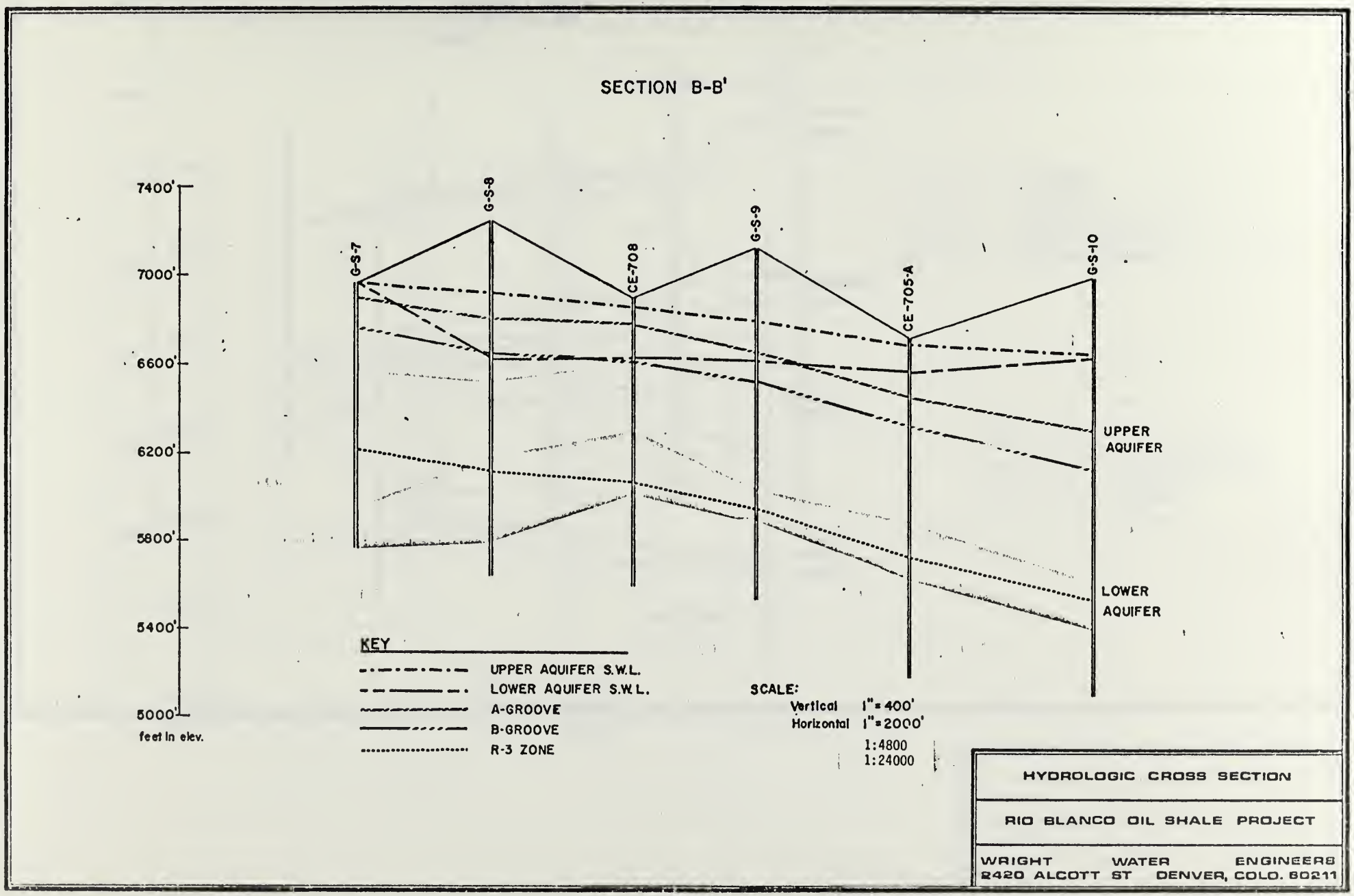
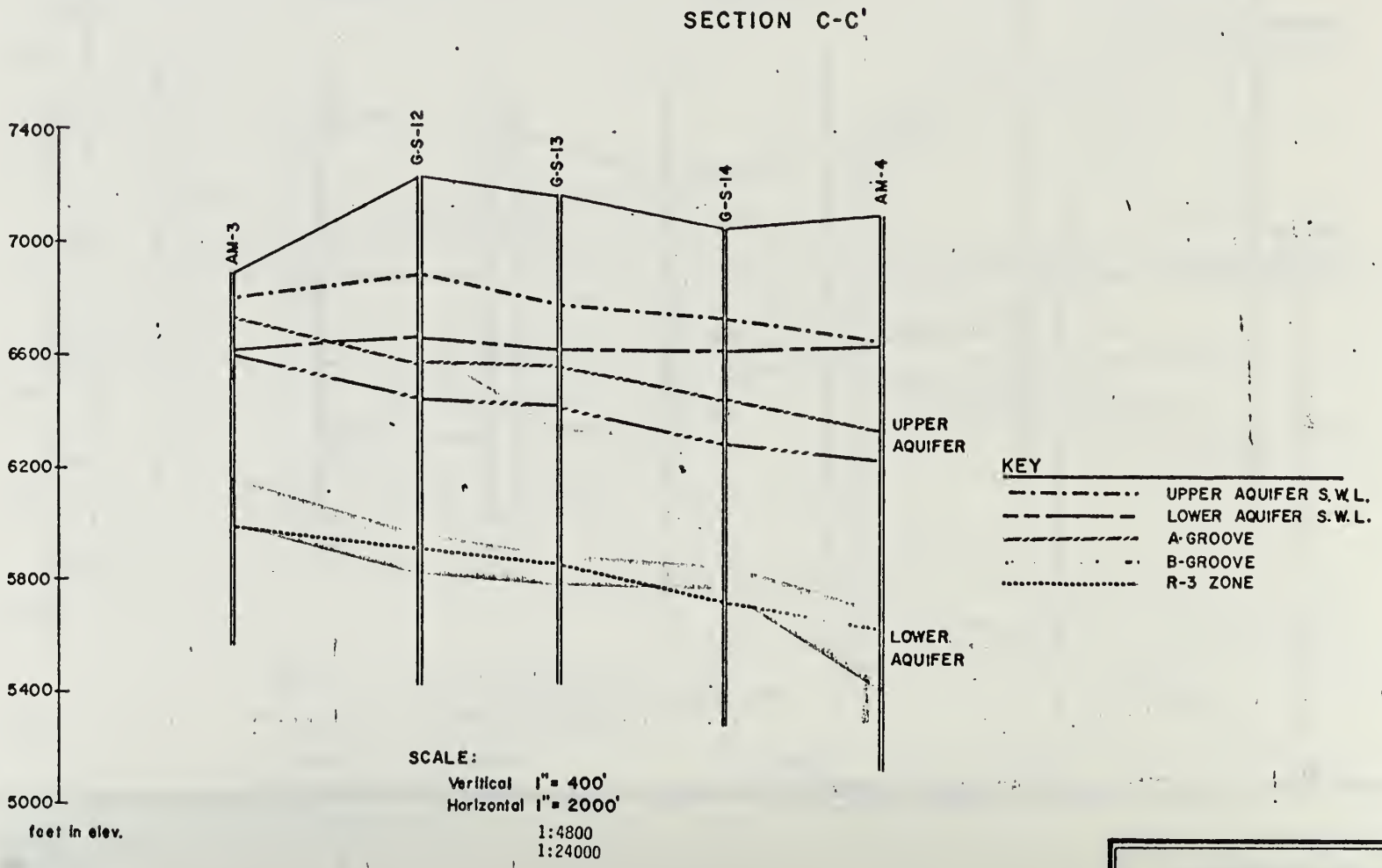

SECTION B-B'
7400'
7000'
6600'
6200'
5800'
5400'
5000'
feet in elev.
G-S-7
G-S-8
CE-708
G-S-9
CE-705-A
G-S-10
UPPER AQUIFER
LOWER AQUIFER
KEY
UPPER AQUIFER S.W.L.
LOWER AQUIFER S.W.L.
A-GROOVE
B-GROOVE
R-3 ZONE
SCALE:
Vertical 1" = 400'
Horizontal 1" = 2000'
1:4800
1:24000
HYDROLOGIC CROSS SECTION
RIO BLANCO OIL SHALE PROJECT
WRIGHT WATER ENGINEERS
2420 ALCOTT ST DENVER, COLO. 80211

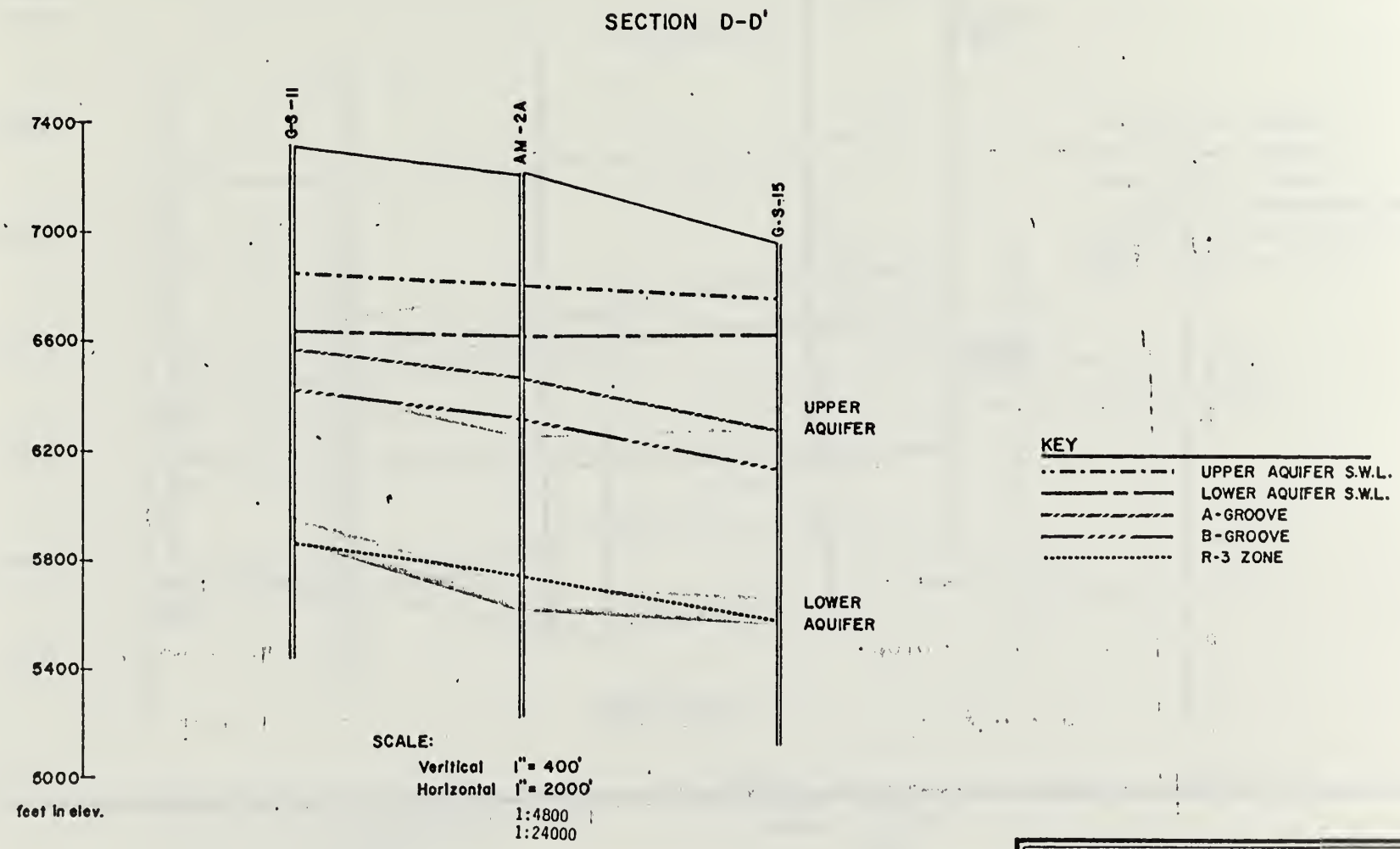
Figure 1.2-87



HYDROLOGIC CROSS SECTION

RIO BLANCO OIL SHALE PROJECT

Figure 1.2-13

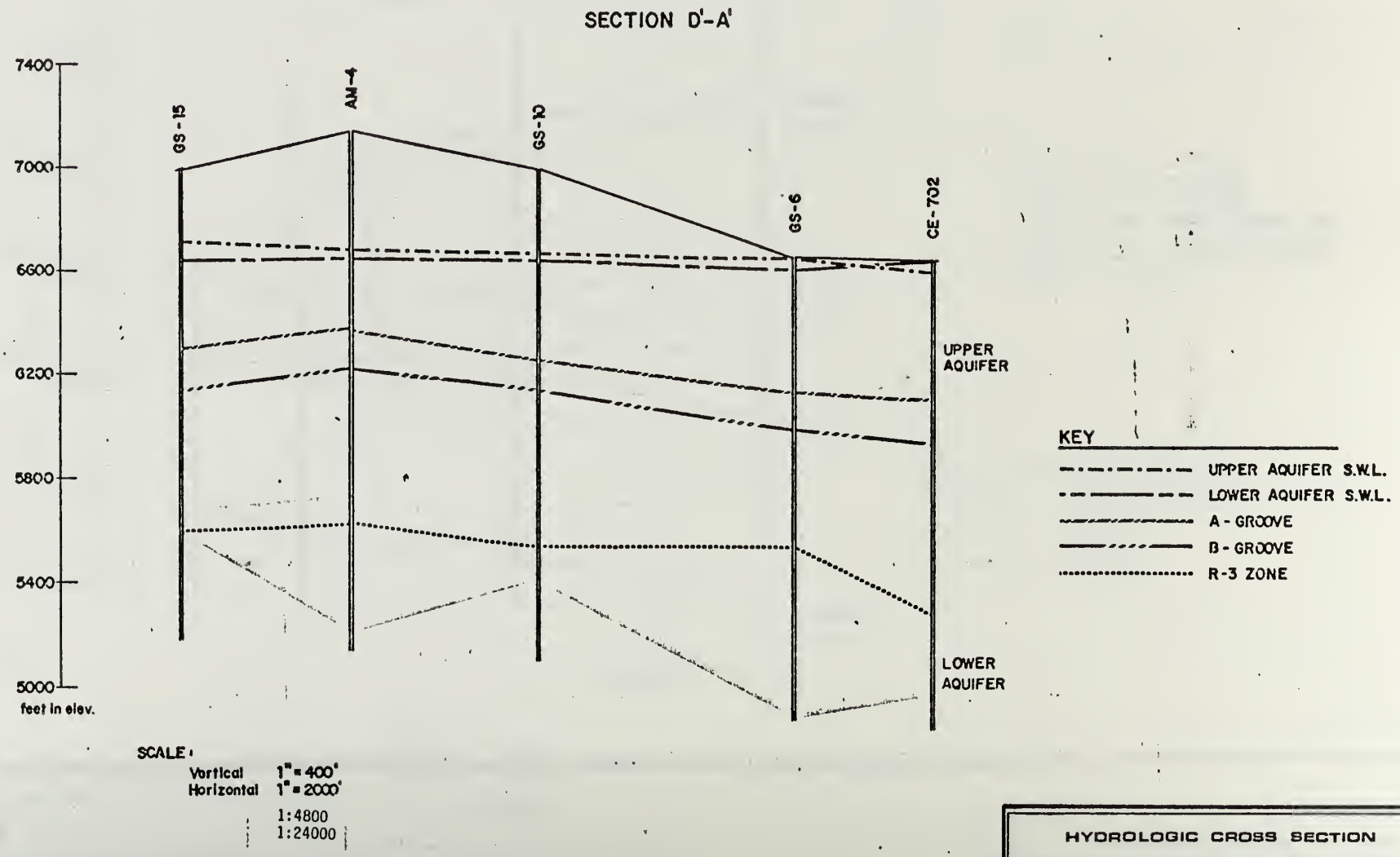


HYDROLOGIC CROSS SECTION

RIO BLANCO OIL SHALE PROJECT

WRIGHT WATER ENGINEERS
2420 ALCOTT ST DENVER, COLO. 80211

Figure 1.2-29



HYDROLOGIC CROSS SECTION

RIO BLANCO OIL SHALE PROJECT

Figure 1.2.20

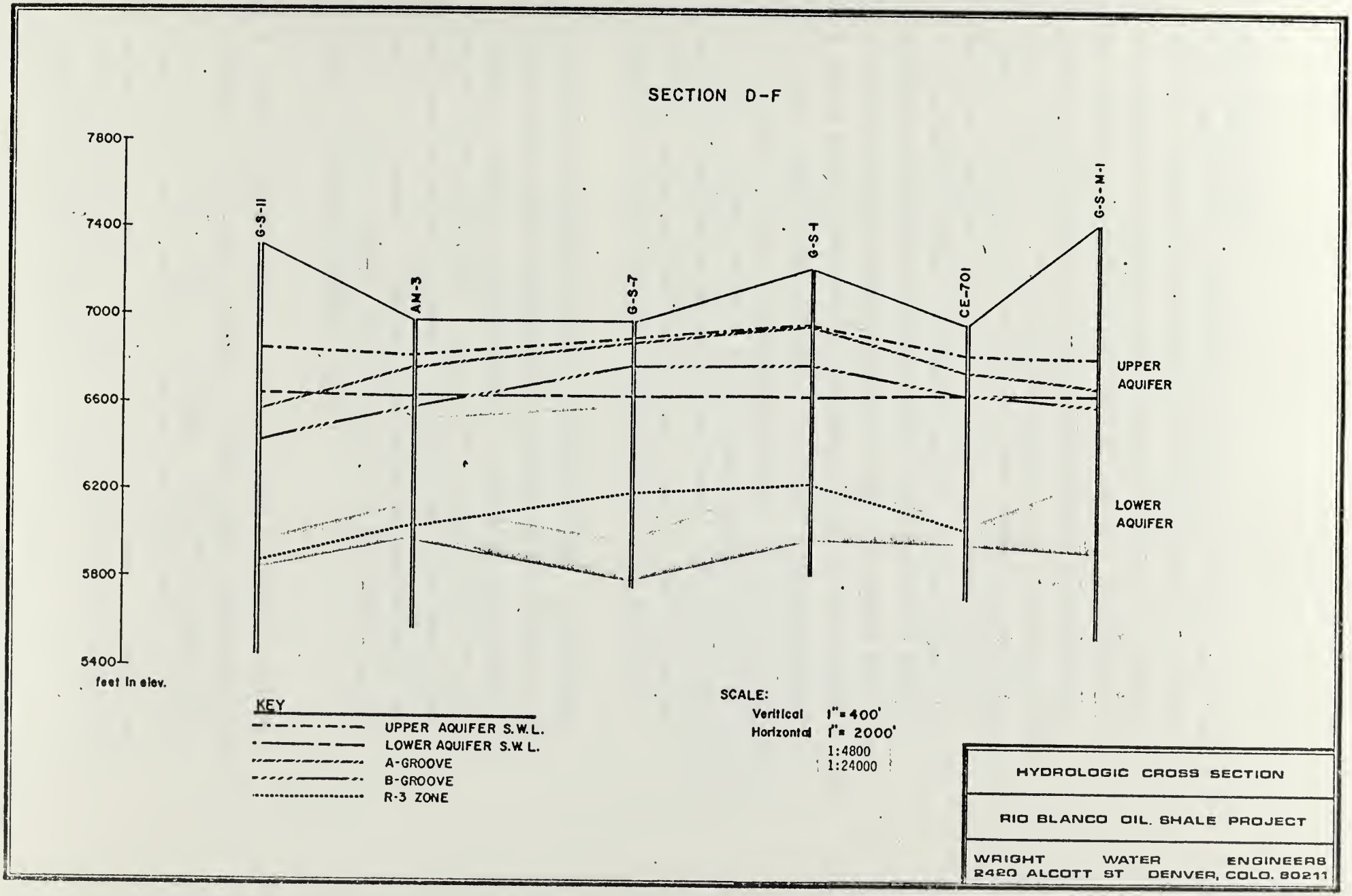


FIGURE III-8

Figure 1.2 21

1.2.5 COMPLETION PROGRAM

A dual monitor hole completion was designed to obtain water levels and water samples from one hole for the two different aquifers. This method of completion also allows the tubing to be removed so individual zones could be tested or pumped. This method of completion for monitor holes has been approved by the Area Oil Shale Supervisor. The completion method is as follows: In most cases, a 5½-inch liner, or 4½-inch liner (depending on original hole size) was run in the hole to a depth of approximately 250 feet below the bottom of the upper aquifer, as indicated by preliminary drilling data. Approximately 200 feet at the bottom of this liner was cemented in place. After the cement had cured, a cement bond log was run to determine the top of the cement so that the liner could be cut off above the cement. The upper portion of the liner was then removed from the hole. A 2-3/8-inch string of tubing was used to set a tension type packer in the liner approximately 30 feet below the top of the liner. This string of tubing with the packer and the liner act as a seal to isolate the two aquifers and allow the lower aquifer system to be monitored.

Two safety joints were designed into the system. These safety joints would allow the packer and possibly up to 60 feet of the tubing to remain in the hole should a situation arise where the packer cannot be pulled. A wash over tool could then be used to retrieve the packer and remaining tubing, or allow the packer and a short amount of tubing to be pushed to the bottom of the hole. The first safety joint is located at the packer and the second is 60 feet above the packer.

A second string of tubing was run to insure that data could be collected for the upper aquifer. In most cases, the second string of tubing is 2-3/8 inches in diameter. However, in some of the older holes, small surface casing was run which only allows the second string to have a diameter of 1-1/2 inches. In both cases, perforated tubing was run where the preliminary data from drilling indicated the upper aquifer to be present.

Some of the holes were not desirable as monitor holes and were cemented from top to bottom as required by the Area Oil Shale Supervisor. Conversion of the RBOSP holes and those holes drilled by previous operators, which include Cameron Engineers, AMOCO, and Tosco, commenced in early October, 1974. The following well conversions were completed by mid-January, 1975. Table shows the current status of each of the holes.

22 holes had been converted to dual monitor holes,
1 converted to a lower aquifer monitor hole,
3 were completed as upper aquifer pump test holes, and
4 were plugged and abandoned.

RBOSP PROGRESS RE

Table 1.2-4

DRILL HOLE COMPLETION SUMMARY

Thirty On-Tract Holes

Drill Hole		Completion	Drill Hole		Completion
G-S	1	U&L	Am	4	P&A
G-S	2-3	U&L	CE -	701	Upper Aquifer Pump Test
G-S	4-5*	U&L*	CE -	702	U&L
G-S	6	U&L	CE -	703	P&A
G-S	7	P&A	CE -	705-A	Upper Aquifer Pump Test
G-S	8	Lower Aquifer Only	CE -	707	U&L
G-S	9	U&L	CE -	708	U&L
G-S	10	U&L	CE -	709	U&L
G-S	11	U&L	TO	1	U&L
G-S	12*	U&L*	TO	2	U&L
G-S	13	U&L	TO	3	Upper Aquifer Pump Test
G-S	14	P&A	G-S	D16	Lower Aquifer Pump Test
G-S	15	U&L	G-S	D17	Lower Aquifer Pump Test
Am	2-A	U&L	G-S	D18	Lower Aquifer Pump Test
Am	3	U&L	G-S	D19	Lower Aquifer Pump Test

Four Off-Tract Holes

Drill Hole		Completion
G-S	M 1	U&L
G-S	M 2	U&L
G-S	M 3	U&L
G-S	M 4	U&L

Totals

Completions in Upper and Lower Aquifers	22
Completions in Upper Aquifer Only	3
Completions in Lower Aquifer Only	5
Holes Plugged and Abandoned	4
Total Number of Holes	34

Am = Amoco Production Company
CE = Cameron Engineers, Inc.
G-S = Gulf-Standard (Indiana)
TO = The Oil Shale Company
U&L = Upper and Lower Aquifer Completions
P&A = Plugged and Abandoned

*Holes Temporarily Modified for Upper Aquifer Pump Testing

1.2.6 UPPER AND LOWER AQUIFER PUMPING TESTS

The pump testing program was begun in January, 1975. This program concluded on June 5, 1975 with the shut down of the pump in G-S 18. Information from these tests is in the process of being finalized. These results will be included in forthcoming reports.

1.2.7 DEEP AQUIFER MONITORING

This monitoring program consists of gathering data on water levels, and water temperature, and collecting samples for testing of various chemical constituents. This program was initiated in December of 1974, and is presently in progress. Baseline data derived from this investigation will be included in subsequent reports.

PROGRESS REPOR

1.2.8 DATA INPUT TO MATHEMATICAL MODEL

A computerized mathematical model has been selected. This model will be used to forecast dewatering and production rates for various pumping and mining configurations. It should be noted, however, that the data input to the model will come from two sources, the first being the information gained from the drilling and pump testing on and around the tract, and the second being the published data for the basin from the USGS.

1.2.9 DEWATERING ANALYSIS

In order to do a dewatering analysis of this magnitude, the mathematical model must first be perfected and the input data finalized. Therefore, it is anticipated that it will be several months before information from the dewatering analysis will be available.

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